From:	Clement, Marcie
To:	"Zimmerman, Breean (ECY)"
Cc:	Smith, Michelle; Clement, Marcie; Sokolowski, Rosana; Bitterman, Deborah; Osborn, Jeff; "Le, Bao"
Subject:	DRAFT Rocky Reach TDG Alternatives Analysis
Date:	Wednesday, March 01, 2017 7:39:16 AM
Attachments:	DRAFT RRH-TDG Alternatives Analysis 3 01 17.docx

PUBLIC UTILITY DISTRICT NO. 1 of CHELAN COUNTY
P.O. Box 1231, Wenatchee, WA 98807-1231 • 327 N. Wenatchee Ave., Wenatchee, WA 98801
(509) 663-8121 • Toll free 1-888-663-8121 • www.chelanpud.org

To: Breean Zimmerman, Washington State Department of Ecology

From: Marcie Clement, Water Resources Specialist
Public Utility District No. 1 of Chelan County (Chelan PUD)

Re: DRAFT Rocky Reach TDG Alternatives Analysis

Ms. Zimmerman:

Attached for your review and comment is the DRAFT Rocky Reach Total Dissolved Gas Alternatives Analysis. This report is step two in a series of FERC/401 requirements. The first was a Year Five report regarding our compliance with the Total Dissolved Gas (TDG) numeric criteria at the Project. If we were not 100% compliant with the water quality numeric criteria, Chelan PUD would then prepare a report that evaluates what measures (operational and structural) may be reasonable and feasible to implement to further reduce TDG production at the Project. Chelan PUD will submit these reports to Ecology, members of the RRFF, and members of the HCP Coordinating Committee.

Please review the attached document and submit any comments you may have on or before 5:00 p.m. April 1, 2017 via email at marcie.clement@chelanpud.org.

If you have any questions, please do not hesitate to contact me.

Thank you,

Marcie Clement | **Water Resources Specialist**
Public Utility District No.1 of Chelan County | 327 N. Wenatchee Ave. | Wenatchee, WA 98801
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DRAFT
TOTAL DISSOLVED GAS ABATEMENT ALTERNATIVES ANALYSIS
Rocky Reach Hydroelectric Project
FERC Project No. 2145

Prepared for
Public Utility District No. 1 of Chelan County
Wenatchee, WA

Prepared by
HDR Engineering, Inc.
Portland, OR

March 2017

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Table of Contents

List of Tables

List of Figures

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List of Abbreviations

12-C High.................. Highest concentration in a day calculated as a rolling 12-hour average

401 Certification........ Chelan PUD's Section 401 Water Quality Certification pursuant to the Clean Water Act

7Q10......................... Highest stream flow for seven consecutive days that would be expected to occur once in ten years

AAA .... Abatement Alternatives Analysis

BO .... Biological Opinion

BPA .... Bonneville Power Administration

cfs............................. cubic feet per second

CWA .... Clean Water Act

DGAS .... Dissolved Gas Abatement Studies

EA............................. environmental assessment

Ecology..................... Washington Department of Ecology

EPA .... Environmental Protection Agency

ERDC .... Engineer Research and Development Center

ESA .... Endangered Species Act

FCRPS .... Federal Columbia River Power System

FERC........................ Federal Energy Regulatory Commission

FPA........................... Federal Power Act

FPC .... Fish Passage Center

GAP.......................... Gas Abatement Plan

GBT .... gas bubble trauma

HCA.......................... Hourly Coordination Agreement

HCP.......................... Habitat Conservation Plan

HCP CC.................... Habitat Conservation Plan Coordinating Committee

Hz .... hertz

JBS........................... Juvenile Bypass System

kcfs .... thousand cubic feet per second

kW .... kilowatt

msl .... mean sea level

MW .... megawatt

NMFS .... National Marine Fisheries Service

PCHB........................ Pollution Control Hearings Board

PMF .... probable maximum flood

PNCA........................ Pacific Northwest Coordination Agreement

PUD .... Public Utility District

RM .... river mile

RPA .... Reasonable and Prudent Alternative

RRFF .... Rocky Reach Fish Forum

TDG .... total dissolved gas

TMDL........................ total maximum daily load

USACE .... United States Army Corps of Engineers

USBOR..................... United States Bureau of Reclamation

USFWS..................... United States Fish and Wildlife Service

USGS .... United States Geological Survey

WAC .... Washington Administrative Code

WQAP....................... Water Quality Attainment Plan

WQS .... water quality standards

Executive Summary

On February 19, 2009, the Federal Energy Regulatory Commission (FERC) issued a new operating license for the Rocky Reach Hydroelectric Project (Rocky Reach Project or Project) which is owned and operated by the Public Utility District No. 1 of Chelan County (Chelan PUD). Pursuant to the requirements of the Federal Power Act (FPA), the FERC adopted in its entirety, the conditions identified within the 401 Water Quality Certification (401 Certification; Ecology 2006) issued on March 17, 2006 by the Washington Department of Ecology (Ecology) pursuant to Section 401 of the CWA (Order 3155).

Section 5.4(1)(d) of the 401 Certification requires a “Determination of Compliance” in the fifth year of the effective date of the Rocky Reach Project License which requires Chelan PUD to prepare a report summarizing the results of all Total Dissolved Gas (TDG) studies performed to date, and describing whether compliance with the numeric criteria had been attained (Ecology 2006). On January 30, 2015, Chelan PUD submitted to the Washington Department of Ecology (Ecology) a Final TDG: Step One, Year Five Compliance Report (Chelan PUD 2015) in accordance with the 401 Certification and Rocky Reach Project License. On July 15, 2015, Ecology issued a letter of determination (Ecology 2015) stating that the Rocky Reach Project “approaches but does not quite achieve full compliance with the applicable numeric criteria for TDG.” However, Ecology also determined that despite not achieving full compliance, aquatic life is not adversely affected.

Section 5.4(1)(e)(2) of the 401 Certification states that if Ecology determines that aquatic life has not been adversely affected by TDG resulting from ongoing Project operations, Chelan PUD shall consult with Ecology and the Rocky Reach Fish Forum (RRFF) to determine if any additional reasonable and feasible measures may exist to meet the TDG standards. If Chelan PUD concludes that no other additional reasonable and feasible measures exist to reduce TDG, Chelan PUD may petition Ecology to modify the standards as detailed in Section 5.4(1)(f-g).

This TDG Abatement Alternatives Analysis (TDG AAA) has been developed consistent with Section 5.4(1)(e)(2) of the 401 Certification (Ecology 2006). It is based upon both historic and the most current regional and site-specific TDG information regarding potential operational and structural abatement measures. It serves as the basis for consultation to determine if any additional reasonable and feasible measures may exist to meet the TDG standards for the Rocky Reach Project.

This analysis compiled all relevant site-specific and regional information regarding both operational and structural TDG abatement alternatives. Results of the literature review indicated that numerous TDG abatement measures had already been compiled and evaluated for their potential as reasonable and feasible TDG reduction alternatives for the Rocky Reach Project (MWH 2003; Schneider and Wilhelms 2005). Remaining potential alternatives identified from results of these assessments formed the basis for a multi-disciplinary review regarding potential operational, coordination, financial, regulatory, and environmental implementation concerns and whether additional alternatives should be included.

Results suggest that all of the alternatives evaluated would likely produce some level of TDG benefit. However, a number of concerns regarding the uncertainty around impacts to generation, environmental resources, and the feasibility of operational implementation were identified. In addition, both of the structural measures identified would likely require significant capital costs to implement with reoccurring operations and maintenance (O&M) costs. Any further evaluation of any of the alternatives in the future will require detailed site-specific assessment and in some cases require additional physical, hydraulic and financial evaluations to more accurately scope the TDG benefit relative to the overall implementation cost. Furthermore, previous site specific TDG assessments have noted that the current spillway infrastructure already have the unintended impact of moderating TDG exchange. Structures such as the nappe deflector, continuous baffle, and high stilling basin end sill provide sufficient energy dissipation over the short length of the stilling basin. The combination of efficient energy dissipation in a shallow stilling basin with an end sill that produces a surface oriented jet entering the adjoining tailwater channel result in TDG pressures that are similar to projects with retrofitted TDG abatement structures (Schneider and Wilhelms 2005).

Existing spillway infrastructure appears to already provide TDG benefits and coupled with the high cost, nominal TDG benefits, and implementation uncertainties and significant additional information needs of adding structural alternatives evaluated during this analysis, it may be more appropriate to continue exploring, in consultation with Ecology, the Rocky Reach Fish Forum (RRFF), and the Habitat Conservation Plan Coordinating Committee (HCP CC), operational alternatives such as a flattened spill configuration. This would allow for a more incremental approach to evaluating TDG benefits versus costs and other potential impacts including to aquatic resources.

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1.0 INTRODUCTION

On February 19, 2009, the Federal Energy Regulatory Commission (FERC) issued a new operating license for the Rocky Reach Hydroelectric Project (Rocky Reach Project or Project) which is owned and operated by the Public Utility District No. 1 of Chelan County (Chelan PUD). Pursuant to the requirements of the Federal Power Act (FPA), the FERC adopted in its entirety, the conditions identified within the 401 Water Quality Certification (401 Certification; Ecology 2006) issued on March 17, 2006 by the Washington Department of Ecology (Ecology) pursuant to Section 401 of the CWA (Order 3155).

Section 5.4(1)(d) of the 401 Certification requires a “Determination of Compliance” in the fifth year of the effective date of the Rocky Reach Project License which requires Chelan PUD to prepare a report summarizing the results of all Total Dissolved Gas (TDG) studies performed to date, and describing whether compliance with the numeric criteria had been attained (Ecology 2006). On January 30, 2015, Chelan PUD submitted to the Washington Department of Ecology (Ecology) a Final TDG: Step One, Year Five Compliance Report (Chelan PUD 2015) in accordance with the 401 Certification and Rocky Reach Project License. On July 15, 2015, Ecology issued a letter of determination (Ecology 2015) stating that the Rocky Reach Project “approaches but does not quite achieve full compliance with the applicable numeric criteria for TDG.” However, Ecology also determined that despite not achieving full compliance, aquatic life is not adversely affected. Ecology also recommended that measures currently in affect to reduce TDG as identified in the Rocky Reach Water Quality Management Plan should be continued.

Section 5.4(1)(e)(2) of the 401 Certification states that if Ecology determines that aquatic life has not been adversely affected by TDG resulting from ongoing Project operations, Chelan PUD shall consult with Ecology and the Rocky Reach Fish Forum (RRFF) to determine if any additional reasonable and feasible measures may exist to meet the TDG standards. If Chelan PUD concludes that no other additional reasonable and feasible measures exist to reduce TDG, Chelan PUD may petition Ecology to modify the standards as detailed in Section 5.4(1)(f-g).

This TDG Abatement Alternatives Analysis (TDG AAA) has been developed consistent with the relevant requirements identified in the Rocky Reach Project 401 Certification (Ecology 2006) as discussed above. It is based upon both historic and the most current regional and site-specific TDG information regarding potential operational and structural abatement measures. It serves as the basis for consultation to determine if any additional reasonable and feasible measures may exist to meet the TDG standards for the Rocky Reach Project. In Section 2.0 the TDG AAA provides background information on the Rocky Reach Project and associated facilities; operations (including fish spill) at the Project and relevant regional coordination agreements; and applicable TDG standards. Also in this section, TDG management within the mid-Columbia River system relative to Rocky Reach Dam and historic and current Rocky Reach Project TDG activities are also described. Section 3.0 details the methods for identifying and evaluating TDG abatement alternatives. Section 4.0 summarizes the analysis of both operational and structural TDG abatement alternatives and Section 5.0 provides summary conclusions and next steps for TDG management at the Rocky Reach Project.

2.0 BACKGROUND

2.1 Rocky Reach Project Overview

The Rocky Reach Project is located at approximately river mile (RM) 474 on the mainstem Columbia River in Chelan County, Washington, approximately seven miles upstream of the city of Wenatchee, Washington (Figure 1). It is the eighth dam upstream from the mouth and is a run-of-river hydroelectric project with limited ability to modify river flows. Rocky Reach Dam is located approximately 43 RMs downstream of the Wells Hydroelectric Project, owned and operated by Public Utility District No. 1 of Douglas County; and 21 miles upstream from the Rock Island Hydroelectric Project, owned and operated by Chelan PUD. The Project has an allowable forebay fluctuation of four feet, with minimum forebay elevation of 703 and maximum of 707 feet above mean sea level (msl) for normal operation (710 under special flood control operation). However, in consideration of system reliability for the regional electric grid, the Project rarely allows the forebay elevation to drop below 704 feet. The forebay elevation is usually maintained between 706 and 707 feet. Tailwater elevation is determined primarily by Project discharge, which is managed under the 1997 Agreement for the Hourly Coordination Agreement (HCA), as described later in this Section. On a daily basis, minimum and maximum discharge is related to the fluctuation in flows released from upstream federal dams, the Grand Coulee Project and Chief Joseph Project (Chelan PUD 2006).

The Rocky Reach Reservoir is 43 miles long and the surface area of the reservoir is approximately 8,235 acres at a flow of 100,000 cfs and forebay elevation of 707 feet. The gross storage capacity of the reservoir at 100,000 cfs is 387,500 acre-feet. The volume of water that the reservoir can contain between the minimum and maximum forebay elevation is 36,400 acre-feet. This storage is useable for capturing or augmenting flow on an hourly basis. If inflow to the Project ceased, the reservoir's useable storage would be sufficient only to run the plant for about two hours. The Chelan and Entiat rivers are tributaries of the Columbia River within the Rocky Reach Reservoir (Chelan PUD 2006).

The inflow to the Project is primarily determined by operations of the Federal Columbia River Power System (FCRPS), which is composed of the federal dams and the accompanying electrical system on the Columbia and Snake rivers in Oregon, Washington, and Idaho. The dams are operated by U.S. Bureau of Reclamation (USBOR) and the U.S. Army Corps of Engineers (USACE), and generate hydropower that is marketed by the Bonneville Power Administration (BPA). The FCRPS is managed for a number of objectives, the primary being flood control, power production, protection of fish resources, recreation, and irrigation. In general, the FCRPS is operated to fill upstream storage reservoirs in June, then provide augmented flows for fish passage and power production through the summer. The FCRPS drafts storage reservoirs to meet power demand and salmon spawning requirements through the fall and winter. Depending on snow accumulations and runoff forecasts, during the spring the reservoirs may be further drafted for flood control and to meet flow targets for downstream juvenile salmon migration periods. FCRPS operations from late May to July focus on managing reservoir levels to meet June refill targets and to be full at the end of July. The FCRPS manages for these objectives using storage releases that pass through the Grand Coulee and

Chief Joseph projects and adjusting for inflow from tributary streams above (the Okanogan, Methow and Entiat rivers) and below (Wenatchee and Snake rivers) the Rocky Reach Project. The FCRPS water management determines the daily, weekly and monthly average flows through the Rocky Reach Project (Chelan PUD 2006).

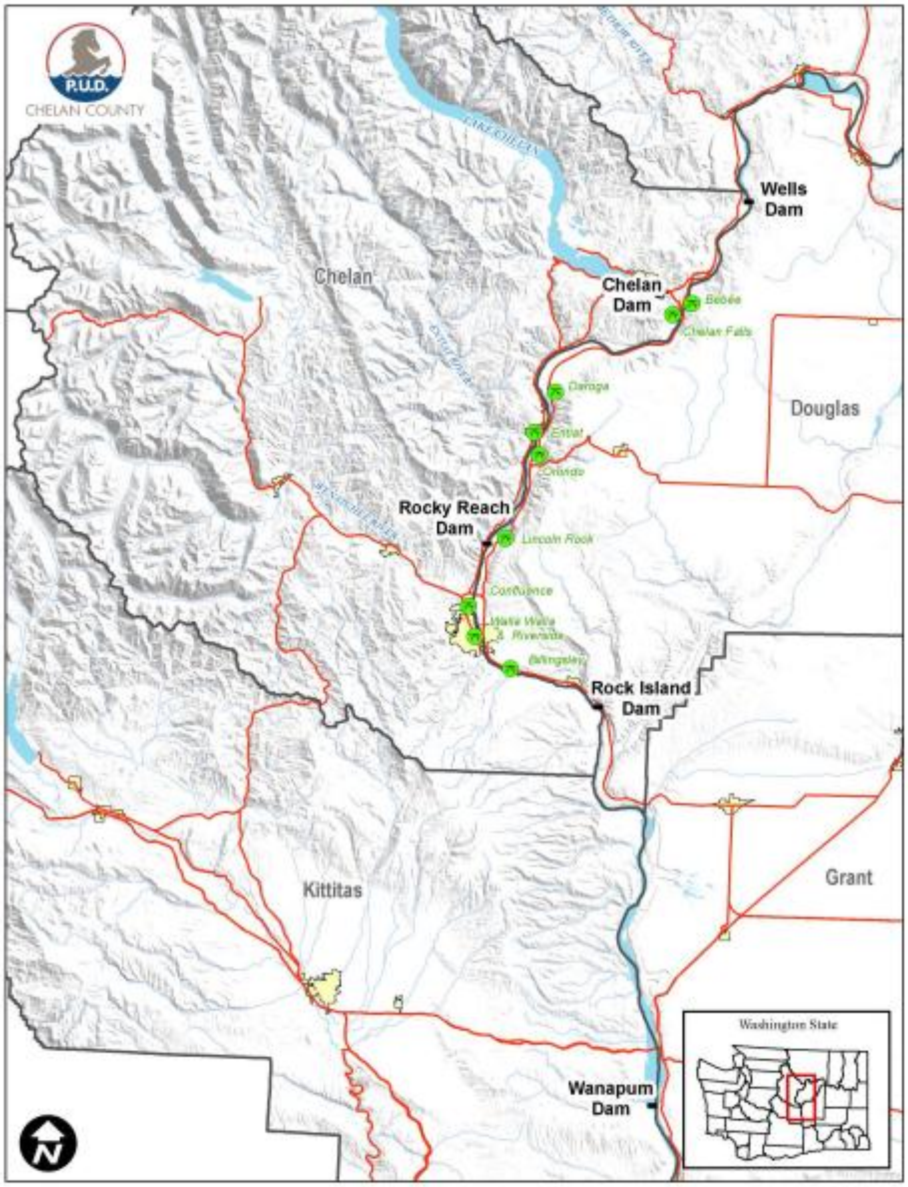

Figure 1. Rocky Reach Hydroelectric Project in Central Washington.

2.2 Rocky Reach Dam

Rocky Reach Dam consists of a concrete-gravity structure approximately 130 feet high and about 2,847 feet long (Figure 2). The dam comprises, from left (east) abutment to right (west) abutment, the east abutment blocks, spillway, center dam, powerhouse, and forebay wall. Fish passage facilities are included in the dam, passing through several of the other structures. Key components of the dam related to TDG management include the spillway and its' operations, powerhouse, and fish passage facilities. These elements are described in more detail below.

Figure 2. Rocky Reach Dam.

2.2.1 Spillway

The dam includes a gated spillway that allows regulation of flows and headwater levels in the Rocky Reach Reservoir (Figure 3). The spillway structure is oriented roughly perpendicular to the flow of the river. The spillway section consists of twelve 50-foot-wide bays separated by 10-foot-wide piers. The crest of the ogee spillway section is at elevation 650 feet. Flow through each bay is controlled by a 58-foot-high radial gate. Each gate is operated by a stationary hoist and is equipped for remote operation from the control room in the Project powerhouse.

The spillway capacity is periodically reviewed pursuant to FERC regulations (18 CFR 12.35). The Periodic Safety Inspection Report submitted to the FERC in 1997 found the spillway to have adequate capacity to pass the probable maximum flood (PMF) with a peak flow of 1,260,000 cfs and headwater elevation of 718.3 feet. This elevation would be above deck level, but below the top of the parapet wall (Chelan PUD 2004).

Figure 3. Rocky Reach Project spillways.

2.2.1.1 Spillway Operations

The standard Project spill configuration (for fish) uses gates 2 through 8 with a minimum discharge per spill bay of about four thousand cubic feet per second (kcfs). The standard spill configuration was designed to create a crown-shaped pattern of turbulent flow below the spillway with decreasing velocities leading toward the upstream migrating adult fishway entrances.

This spill pattern provides favorable guidance conditions for adult migrant salmon and steelhead. This spill configuration and alternate patterns were tested and it was determined this pattern was as good as, if not better than, the alternate patterns for upmigrating salmonids (Schneider and Wilhelms 2005). The same pattern is used for juvenile downstream migrating fish passage spill. During spill operations, whether for juvenile fish passage, TDG management, or for other purposes, the gates are operated via a computer automated system that follows the spill pattern (Chelan PUD 2016).

Note that although the above referenced crown-shaped pattern may be as good as, if not better, than tested alternate patterns for upstream migrating adult salmonids, it may not be ideal for TDG. According to Section 5.4(1)(b)(6) of the 401 Certification, Chelan PUD shall study alternative spillway operations using any of gates 2 through 12 (refer to Section 2.5.2.8 below for more information on additional evaluation activities).

In general, there are seven scenarios that may result in spill at Rocky Reach Dam. With the exception of the juvenile salmon Fish Spill scenario, to reduce negative impacts of all other spill scenarios, Chelan PUD has completed a TDG Operational Plan that can be implemented, as needed. The TDG Operational Plan is attached to annual the Gas Abatement Plan (GAP). Chelan PUD anticipates implementation of the TDG Operational Plan to be an operational function, requiring no structural modification to the Project (Chelan PUD 2016).

Fish Spill

Voluntary spill for fish is a generally ineffective method of bypassing downstream migrating juvenile salmon and steelhead away from the turbines at Rocky Reach Dam (Steig et. al., 1997) and, consequently, is not considered a solution for the long-term fish passage program under the Anadromous Fish Habitat Conservation Plan (HCP). To minimize or eliminate the need for fish-spill, Chelan PUD has focused efforts to increase the fish passage efficiency and survival through the juvenile bypass system (JBS).

The JBS continues to be the most efficient and safe non-turbine route for downstream migrating juvenile fish passage at the Project. The JBS does not require spill for its operation.

Spring Fish Spill Operations

Operating the JBS exclusively, Chelan PUD has been able to meet the HCP survival standards for the three spring migrants (spring/yearling Chinook, steelhead, and sockeye). Chelan PUD will continue operating the JBS exclusively, with no voluntary spill during the spring (typically from April to late May/early June) which significantly reduced TDG from the pre-fish bypass condition of 15 percent to 25 percent spill of the day average river flow in April and May (Chelan PUD 2013)

Summer Fish Spill Operations

In 2016, summer spill at Rocky Reach for subyearling Chinook was nine percent of day average flow. Commencement of summer spill has been determined using run-timing information at Rocky Reach Dam via the JBS. Summer spill generally begins in early June and ends in mid-August when 95 percent of the migration of subyearling Chinook has passed the Project.

Due to tag technology limitations and uncertainties regarding their life history (outmigration behavior) no survival studies for subyearling Chinook have been conducted since 2004, nor are any planned within the next three years (Chelan PUD 2016).

Flow in Excess of Hydraulic Capacity

The minimal storage and limited hydraulic capacity of the Project occasionally force Chelan PUD to spill water past the Project. This spill is required to maintain headwater elevations within the limits set by the Project's FERC license (707 feet), to prevent overtopping of the

Project, and to maintain optimum operational conditions. When spilling for fish or due to excess inflow or generation, the spillway is operated using gate settings that have been shown to limit TDG production and meet fish passage requirements (Schneider and Wilhelms 2005).

Plant Load Rejection Spill

This type of spill occurs when the plant is forced off line by an electrical fault, which trips breakers, or any activity forcing the units off line. This is an emergency situation and generally requires emergency spill. When the units cannot pass flow, the flow must be passed by other means, such as spill, to avoid overtopping the dam (Chelan PUD 2016).

Immediate Replacement Spill

Immediate replacement spill is used to manage TDG levels throughout the Columbia River basin. The Technical Management Team which includes the National Marine Fisheries Service (NMFS), USACE, and BPA, manages this spill. Immediate replacement spill occurs when TDG levels are significantly higher in one river reach than they are in another reach. To balance the TDG levels throughout the basin, spill is reduced and generation increased in the reach with high TDG levels and the energy is transferred to reaches with lower TDG levels where spill is increased. The result is higher generation in the reaches with high TDG levels, increased spill in reaches with lower TDG levels, and equal distribution of TDG levels throughout the basin (Chelan PUD 2016).

Maintenance Spill

Maintenance spill is utilized for any maintenance activity that requires spill to assess the routine operation of individual spillways and turbine units. These activities include forebay debris flushing, checking gate operation, gate maintenance, and all other maintenance that would require spill. The FERC requires that all spillway gates be operated once per year. This operation requires a minimal amount of spill for a short duration annually and is generally accomplished in conjunction with fish passage spill operations (Chelan PUD 2016).

Error in Communication Spill

Error in communication with the USACE Columbia River Basin Water Management Division, including computer malfunctions or human error in transmitting proper data, can contribute to spill. Hourly coordination between hydroelectric projects on the river minimizes this type of spill, but it does occur occasionally (Chelan PUD 2016).

Reduced Generation Spill

Reduced electric demand on the system can, at times, result in the need to spill water at run-of the river projects such as Rocky Reach. Hourly coordination between hydroelectric projects on the river can minimize this type of spill, but it does occur (Chelan PUD 2016).

2.2.2 Powerhouse

The powerhouse is an indoor-type, approximately 1,088 feet long by 206 feet wide and 218 feet high. It includes eleven generating units and a service bay. Each unit is housed in an independent block of reinforced concrete 86 feet wide by 206 feet long (parallel to the flow). Units 1 through 7 were part of the original Project construction completed in 1961. At the time of original construction, spaces were prepared for Units 8 through 11, which were added in 1971. Units 1 through 7 generators are each rated at 111,150 kilowatt (kW), but these units are turbine limited to 140,000 hp or 105,000 kW. Units 8 through 11 generators are each rated at 125,400 kW for an installed capacity for the 11 units of 1,236.6 megawatts (MW). In 1995 through 2003, all the turbine runners were replaced with new more fish-friendly and efficient turbine runners. In 2002, FERC revised the installed Project capacity to 1,237.4 MW with the authorization of a micro-turbine. Operation of the Project is automated and can be controlled locally by full-time operators in the Project control room or remotely from Chelan PUD's dispatch center in Wenatchee (Chelan PUD 2004).

Maintenance and servicing of the equipment in the powerhouse is facilitated by two overhead, traveling-bridge cranes. These cranes have a capacity of 250 tons, with an auxiliary hook capacity of 25 tons. The cranes are powered by electric motors and operated using remote radio controls (Chelan PUD 2004).

Each generating unit has three intake openings. Intakes for the units are equipped with two sets of slots, the upstream slot is typically used for trashracks and the downstream slot is used for placement of headgates when a unit needs to be de-watered. Trashracks and headgates are handled using the intake deck gantry crane. This crane has a capacity of 150 tons with an auxiliary hook capacity of 10 tons. In addition, a high-speed 45-ton hoist is available which can be suspended from the gantry crane's main hooks (Chelan PUD 2004).

Draft tubes for the units are equipped with slots for placement of bulkhead gates used to de-water the units. Draft tube bulkhead gates are handled using the draft tube deck gantry crane. This crane has a capacity of 60 tons, with an auxiliary hook capacity of 6 tons (Chelan PUD 2004).

The powerhouse service bay is a concrete structure forming the corner between the forebay wall and Unit 1 of the powerhouse. The service bay is a rectangular structure approximately 170 feet long and 142 feet wide. The short dimension of the structure is parallel with the upstream face of the powerhouse. The service bay is a combination of mass and reinforced concrete construction. The headworks, foundation mat, and soil and water retaining sections of the structure are constructed of mass concrete. The walls, floor slabs, beams, and columns are constructed of heavily reinforced concrete (Chelan PUD 2004).

2.2.3 Fish Passage Facilities

Facilities for passage of adult anadromous fish moving upstream to spawn are an integral part of the Project. A single fishway with three entrances provides for upstream migration. Entrances to the fishway are between spillway bays 8 and 9, at the center dam, and at the powerhouse service bay. Fish using any of these entrances follow passages to the center dam, and then along the downstream side of the powerhouse to a fish ladder along the forebay wall. Just before reaching the Rocky Reach Hydroelectric Project reservoir, the fish ladder passes through a fish counting station, which is part of the visitor facilities near the right abutment. Attraction water for the fishway passages is provided from the tailrace by three hydraulic turbine-driven pumps with a capacity of 3,500 cfs. The adult fish passage facilities are monitored and controlled from a dedicated control room on the draft tube deck near the middle of the powerhouse (Chelan PUD 2004).

The JBS was constructed at the Rocky Reach Project in 2002-2003 to provide for safer, more efficient passage of downstream-migrating fish. The JBS design is based on testing conducted from 1985 through 2002. The system consists of a forebay surface collector, intake screens on two generating units, a large-diameter bypass conduit to convey downstream-migrating fish past the dam, and a sampling facility (Chelan PUD 2004).

The surface collector is located adjacent to the forebay wall and generating units 1, 2 and 3. It includes two channels, each 20-feet wide extending to a bottom elevation of 650 feet. In addition to the surface collector, Units 1 and 2 are equipped with intake screens that collect fish from the intake area. Fish from both the surface collector and intake screens are delivered to the bypass conduit. The bypass conduit is a pipe up to 9 feet in diameter, routed along the downstream side of the powerhouse and spillway, through the sampling facility, to an outfall point approximately 1,700 feet downstream of the dam and 450 feet from the east bank (Chelan PUD 2004).

Juvenile fish are collected and examined, as necessary, at the sampling facility on the east bank downstream of the spillway. Chelan PUD's fish and wildlife crew collects species composition and fish condition data. Fish are also collected for ongoing survival and behavioral studies at Rocky Reach and Rock Island project dams (Chelan PUD 2004).

2.3 Project Operations for Power and Fish Resource Protection

2.3.1 Overview of Project Flow Regulation and Generation

The amount of flow that enters the Rocky Reach Project is regulated by releases from the federal Grand Coulee Project, which essentially dictates the flowage curve for all downstream projects on the Columbia River hydropower system. Seasonal demand for hydroelectric generation is governed by the Pacific Northwest Coordination Agreement (PNCA);[1] however, non-power constraints such as flood control operations and the FCRPS Biological Opinion also dictate flow releases from the Grand Coulee Project. In the mid-Columbia, five non-federal hydroelectric projects (Wells, Rocky Reach, Rock Island, Wanapum and Priest Rapids projects) cooperate with each other and with the federal projects immediately upstream (Grand Coulee and Chief Joseph projects) through the HCA to efficiently manage these releases to meet power demand and non-power operations for fish protection under the Hanford Reach Agreement. The HCA is set up to meet the daily demands of power load peaking while maintaining reservoir

[1] Coulee Project releases are governed by the PNCA. All generating utilities in the Northwest, with the exception of Idaho Power Company, are parties to the PNCA. The PNCA, in conjunction with the Canadian Treaty of 1964, provides a plan for optimizing water releases to meet power and non-power requirements on a seasonal basis.

levels as stable and full as possible. These seven projects are the primary source for electricity load regulation for the entire Northwest (Chelan PUD 2006).

Hydropower is a unique energy resource because of its ability to start and stop with relative ease compared to other energy sources, such as coal or natural gas, which require hours or days to bring additional capacity online to meet increased demand. If generation and load requirements do not match, the electrical system becomes unstable. Load regulation is the ability to adjust generation as often as every four seconds so that at every moment in time, the generation of the interconnected electrical system matches the load requirements being placed upon it by customer demand. The BPA uses the Grand Coulee and Chief Joseph projects as its primary tools to align supply with demand signals, while all major Northwest investor-owned and some public power utilities have shares of the generation output of the five mid-Columbia non-federal projects. These projects are used for load regulation because of their abilities to regulate river flows on a daily or hourly basis (Grand Coulee and Chief Joseph) or, in the case of the Rocky Reach Project, for a unique ability to adjust to changes in power demand on a real-time basis (Chelan PUD 2006).

Operation of the Rocky Reach Project is completely automated, including decisions to start, stop and adjust the output of the 11 generating units to achieve maximum efficiency. The automated functions are backed up with around-the-clock on-duty plant operators who monitor operations and can over-ride computer control if needed. When a generation request is transmitted from the central computer to the Rocky Reach Project's on-site computers, the most efficient way to meet the request is determined and implemented. Units 1 through 11 are adjustable blade Kaplan units and are efficient over a wide range of operating conditions. During the downstream juvenile salmon migration, operations are adjusted to assure that turbine units 1-2, which support the JBS, are operating at all times and other units near the JBS are operated in preference to turbines further from the bypass entrance (Chelan PUD 2006).

Spillway releases to pass water in excess of turbine capability or load requirements, or for fish passage, are also controlled by computer. When the headwater level exceeds operator-set maximum points, gates are automatically opened to pass the excess flow. During fish passage operations, the sequence and amounts of gate opening can also be adjusted to maximize the effectiveness of the water being spilled for fish passage. During high water years, the Project operates at a higher plant factor and is more often subject to spill to pass flows in excess of plant turbine capacity. A higher plant factor implies that the Project is able to operate at or near full load for longer periods of time without drafting the storage from the reservoir. As flows increase, tailwater effects reduce plant capacity due to higher tailwater levels and lower available gross head. Under lower water supply conditions, the number of hours that the plant can sustain operations at or near peak load diminishes (Chelan PUD 2006).

While the Rocky Reach Project has little control over river flow, operations do have some immediate impact on control of hourly fluctuations in reservoir level and discharge. The Rocky Reach Project is managed in accordance with the resource optimization framework set up through the HCA (Chelan PUD 2006). The history and purpose of the HCA is described below.

2.3.1.1 Mid-Columbia Hourly Coordination Agreement

The HCA was first signed in 1974 as a one-year agreement. It was then renewed in a series of longer-term agreements. The current agreement was signed in 1997 and extends until June 30, 2017. The HCA is signed by the project owners (Chelan PUD, Douglas PUD, Grant PUD, USACE, and the USBOR), as well as all purchasers and participants of the projects, including the BPA. The HCA sets forth terms for operating the five non-federal mid-Columbia hydroelectric projects and two upstream federal projects, Grand Coulee and Chief Joseph, in a coordinated manner through the “middle” stretch of the Columbia River (Chelan PUD 2006).

The objectives of the HCA are to: (1) coordinate the hydraulic operation of the projects to optimize the amount of energy from the available water consistent with the needs to both (i) adjust the total actual generation to match the total requested generation, and (ii) operate within all parties’ power and non-power requirements; (2) provide flexibility and ease of scheduling generation for the projects through centralized coordinated scheduling and to provide flexibility in scheduling project generation; and (3) to minimize unnecessary project generation changes, including unit starts and stops to the extent this objective is consistent with the other objectives of the HCA (Chelan PUD 2006).

Under the HCA, the system’s federal and non-federal hydroelectric projects cooperate to efficiently manage Grand Coulee Project flow releases in order to meet the daily demands of power load peaking while maintaining reservoir levels as stable and full as possible. The operating strategy under the HCA includes specific algorithms related to reservoirs for power production, spill prevention, and downstream reservoir refill. In general, spill is avoided unless necessary for fish survival, since it wastes energy. To prevent spill, the total system of projects attempts to meet load by drafting from the project on the system that results in the least head loss. Spill is reduced or prevented where possible, by drafting a project downstream of the point of spill and reducing discharge above the point of spill, if it is anticipated that the drafting project’s reservoir can refill within a prescribed time interval. Additional generation produced by the downstream draft is intended to reduce the coordinated request upstream of the point of spill, thereby reducing the inflow to the project being forced to spill. The net effect of this operation is to reduce involuntary spill, where hourly inflow to a project could exceed the hydraulic capacity of the powerhouse, thus forcing the project to spill water. This minimization of spill is desirable from a water quality standpoint, in that it minimizes the occurrence of elevated levels of TDG to only years with high flows and to voluntary spill provided to improve fish survival (Chelan PUD 2006).

Each project on the system generates the most power when a release from Grand Coulee Project moves into its reservoir. The Project receiving the flow of water moving through the system generates at the highest plant factor necessary to provide as much power as possible, regardless of whether that particular project’s customers are making the request at that time. All power requests and non-power requirements are collected and tracked by a computer at Grant PUD’s headquarters (Ephrata, Washington) which serves as "Central" to the operation. This computer optimizes movement of water to maximize generation while keeping the reservoirs as full as possible. Participants in the HCA make requests for power from the central system in real time. The computer assigns each project a desired generation level so that all load requests are satisfied in a manner that optimizes the combined operational efficiency of all of the participating projects. This means that a power purchaser with an agreement with the Rocky Reach Project may actually be receiving power generated at Priest Rapids Project at a certain time of the day. The situation may be reversed when it is more efficient to a Grant PUD's purchaser to receive power generated at the Rocky Reach Project. The programming for the computer has evolved through many years of refinements and is intended to achieve the highest overall level of efficiency for the participating projects (Chelan PUD 2006).

The HCA reduces water level fluctuations that would otherwise occur in both the reservoirs and tailraces of projects, because the higher efficiency is achieved by keeping the reservoirs as full as possible. Most of the mid-Columbia reservoirs have some backwatering (encroachment) effect on the tailrace of the project upstream, and the backwatering also reduces the magnitude of water level fluctuations in the tailwater that result from changes in plant discharge. In the absence of the HCA, the tailwater levels at each plant would fluctuate based on discharge of inflows originating from the Grand Coulee Project, potentially exacerbated by additional fluctuation as individual projects drafted and refilled their useable storage while meeting load requests that are not synchronized with the flow of water through the mid-Columbia River. The HCA prevents compounding effects and actually reduces water level fluctuations by dampening the effect of daily swings in flow releases from Grand Coulee Project (Chelan PUD 2006).

While the HCA allows participants to take advantage of these resource efficiencies in real time, it also ensures that each participant receives such power benefits in accordance with its rights to the generating assets. The computer keeps accounting records that recognize the varying generation obligations of each participating project. The computer's accounting programming permits the shifting in time of actual generation from one project to another by means of "coordinated exchange." As a result, each project generates when and at the level that is most efficient, and the contractual obligations of each project are met in the most cost-efficient manner possible. A paper account tracks when a project is generating less or more power than it needs to fill its obligations. In any 24-hour period, each project will have generated more than its customers require at certain times of the day and less than its customers require at other times of the day. Over approximately a 24-hour period, there is essentially no discrepancy between a single project's actual generation under the HCA and the customer demand it has worked to fulfill (Chelan PUD 2006).

2.3.1.2 Role of Rocky Reach and other Mid-Columbia Projects in Meeting Regional Energy Requirements

Federal hydropower projects throughout the Columbia and especially the Snake River system are subject to many operational restrictions intended to protect fish resources. These restrictions have prevented some projects from fluctuating power generation significantly in order to meet local and regional power demand. In response, the BPA relies almost entirely on the ability of the mid Columbia projects to respond to demand through regional load following outlined in the HCA. Essentially, the seven mid-Columbia projects perform all of the load regulation for the Northwest electrical system. The operational restrictions placed on Grant PUD projects through the Hanford Reach Agreement shifts the burden of meeting local and regional load following demand even more heavily onto the Rocky Reach and Wells projects.

The main role of the Rocky Reach Project in the HCA is to utilize ramping (change in generation output) to meet the burden of regional load following. However, despite the system's heavy reliance on Rocky Reach's ramping capability, the Project manages to perform this role with the second smallest amount of useable reservoir storage in the Mid-Columbia power system and a maximum reservoir fluctuation of only four feet.

The Rocky Reach Project is fulfilling its appropriate role under the HCA from the perspective of both fish and power obligations. It follows load in a manner that cannot be duplicated by the Wanapum and Priest Rapid projects (due to Hanford Reach Agreement considerations), thereby allowing those projects to manage their reservoirs in order to meet obligations for fish. If Rocky Reach were similarly restricted in operation, there would be implications for the entire Northwest electricity market, which would demand replacement power. This could be problematic in other environmental respects, given the amount and likely sources of replacement power. Hydro units are able to adjust to meet load much more quickly than thermal (gas, oil, coal, or nuclear) systems, and much more efficiently. Hydropower units can start and stop quickly, matching load demands on a four-second basis and reducing the need for significant reserves. If the load regulating ability of the mid-Columbia was lost due to restrictions, new generating facilities would need to come online to replace the hydropower system's ability to respond to electrical demand on a four-second basis. In order to replace this kind of flexible resource in a manner that would provide sufficient reserves for immediate response to regional load, as much as 2,000 megawatts of additional thermal generation would be required. These plants would be operated much more inefficiently, have negative air quality impacts and increase greenhouse gas emissions (Chelan PUD 2006).

2.3.2 Current Operations

Chelan PUD operates the reservoir with a normal maximum headwater elevation of 707 feet. The minimum allowable headwater level is 703, but drafting of headwater below 705 feet is infrequent (less than 2 percent of the time). Although the Project has a total useable storage of 36,400 acre-feet between headwater 707 and 703 feet, not all the storage is used, except in an emergency. Standard procedure is to not reduce forebay elevation below 704 feet because the bottom foot of storage is needed in reserve to maintain stability in the power grid. The reservoir's total useable storage is sufficient to run the plant for about two hours (at average flows) without additional inflows. In normal operations, this storage can be used to increase outflow over the inflow by about 10,000 cfs over a full day.

During a normal water year, the plant operates at a plant factor of 55 percent (average flows are only sufficient to operate at 55 percent of the Project's maximum generating capacity). During high water years, the Project operates at a higher plant factor but is also more often subject to spill to pass flows in excess of plant turbine capacity. When operating at a higher plant factor, the Project is able to operate at or near full load for longer periods of time without drafting the storage from the reservoir. Under lower water supply conditions, the number of hours that the plant can sustain operations at or near peak load diminishes (Chelan PUD 2006).

2.3.3 Hanford Reach Fall Chinook Protection Program

Chelan PUD has participated since 1988 in flow management operations for the protection of fall Chinook salmon that spawn in the Hanford Reach of the Columbia River. These joint operations were originally specified in the Vernita Bar Agreement, which provided protective operations from the beginning of spawning activity (late October) through incubation until the end of the emergence period (late April to early May). The Vernita Bar Agreement was scheduled to expire in 2005, concurrent with the expiration of Grant PUD's License for the Priest Rapids Project (Chelan PUD 2006).

Research in the late 1990s found that flow fluctuations in the Hanford Reach can also adversely affect survival of fall Chinook fry during the first few weeks after emergence. Due to the extensive areas of backwater channels and shallow gravel bars in the Hanford Reach, changes in river elevation associated with daily and weekly flow fluctuations can cause fish to be stranded in areas where they are exposed to mortality from dewatering, or heat stress and predation in shallow pools that become isolated from the main river channel. To address these issues, Chelan PUD has voluntarily cooperated with Grant PUD, BPA and Douglas PUD to enable Grant PUD to operate the Priest Rapids Project to reduce flow fluctuations. These voluntary operations, initiated in 1999, included research covering alternative operating methods that resulted in development of a long-term operating plan that has replaced and improved upon the Vernita Bar Agreement (Chelan PUD 2006).

The new agreement, the Hanford Reach Agreement, has been executed by most of the original parties to the Vernita Bar Agreement. In addition to Chelan PUD, this new agreement includes the following parties; Grant PUD, BPA, Douglas PUD, WDFW, NMFS, and the Colville Confederated Tribe. The new agreement includes operations for the protection of fall Chinook salmon from the beginning of spawning through the early rearing period when Chinook fry are susceptible to stranding. The new agreement requires the same actions from Chelan PUD as the original Vernita Bar Agreement, but includes the additional time period that extends from April into June. This includes supporting Grant PUD's operations through the HCA and providing up to one foot of draft from the reservoir (Chelan PUD 2006).

2.3.4 Anadromous Fish Agreement and Habitat Conservation Plan

A 50-year agreement regarding protection of anadromous salmon and steelhead at the Project has been incorporated into the Project's License. The Project has special operations and facilities that are used to meet the survival objectives of the HCP, which are 93 percent survival for juveniles passing the Project and 91 percent combined survival of juvenile and adult salmon and steelhead passing the Project. Operations for the Project under the HCP use the JBS, installed in 2003, as the primary method for safely passing juvenile salmonids. Under the HCP, Chelan PUD continuously operates the JBS system from April 1 to August 31 each year. The spillway is also used, when needed to supplement the JBS, to provide a safe passage route. Spill levels are set by the HCP CC based on the results of past survival studies. Due to the performance of the JBS in passing yearling Chinook, sockeye, and steelhead, spill is not currently needed to meet survival standards for these species. Spills will continue to be used for passing subyearling Chinook salmon until such time that the JBS or other tools for improving fish survival have met the survival standards. Spill, when required, is provided over a time period that encompasses 95 percent of each species' downstream migration. Spill levels in 2016 were 9 percent of the estimated daily average flow for subyearling Chinook (Chelan PUD 2016). After completion of survival studies, spill will supplement the JBS as necessary to achieve the survival standards. Spill is managed to reduce adverse effects on water quality and meet water quality standards for TDG (Chelan PUD 2006).

In 2020, as part of an HCP "check in", Chelan PUD is required to conduct a juvenile survival study at Rock Island Dam using representative species to confirm that past juvenile survival results for yearling Chinook, sockeye, and steelhead are still being upheld. A similar type of study is currently scheduled at Rocky Reach Dam in 2021 (L. Keller, personal comm.).

2.4 TDG Criteria and Regulatory Framework

Chapter 173-201A of the WAC defines the water quality standards (WQS) for the surface waters of Washington State. Under the WQS, TDG shall not exceed 110 percent at any point of measurement in any state water body. However, the standards exempt dam operators from this TDG standard when the river flow exceeds the seven-day, 10-year-frequency flood (7Q10). The 7Q10 flow is the highest calculated flow of a running seven consecutive day average, using the daily average flows that may be seen in a 10-year period. The 7Q10 total river flow for the Rocky Reach Project was calculated following methods from the United States Geological Survey (USGS) Bulletin 17B, "Guidelines for Determining Flood Flow Frequency" and determined the value to be 252,000 cfs (Ecology et. al. 2004).

In addition to allowances for natural flood flows, the TDG numeric criterion (110 percent) may be adjusted to aid fish passage over hydroelectric dams when consistent with an Ecology-approved GAP per WAC 173-201A-200(1)(f)(ii)). The increased levels of spill resulting in elevated TDG levels are authorized by Ecology to allow salmonid smolts a non-turbine downstream passage route that is less harmful to fish populations than caused by turbine fish passage. This TDG exemption provided by Ecology is based on a risk analysis study (NMFS 2000). The GAP must be accompanied by fisheries management and physical and biological monitoring plans and is approved on a per application basis for juvenile fish passage at dams on the Columbia and Snake rivers. This TDG exemption comprises three separate standards to be met by dam operators.

1. TDG shall not exceed 125 percent as a maximum one-hour average in the tailrace of a dam;
2. TDG shall not exceed 120 percent in the tailrace of a dam as measured as an average of the 12 highest consecutive hourly readings in any 24-hour period (12-C High); and
3. TDG shall not exceed 115 percent in the forebay of the next dam downstream as measured as the 12-C High.

Each year, the Rocky Reach Project operates under this TDG exemption during its fish spill season (generally April to August) per an Ecology-approved GAP. Outside of the fish spill season, Rocky Reach Dam is required to adhere to the general TDG WQS numeric criterion of 110 percent.

2.4.1 Designated and Beneficial Uses

It is important to note that in addition to numeric criteria, WQS standards contain narrative criteria and an anti-degradation policy that requires that beneficial and designated and existing water uses be “maintained and protected” 40 CFR § 131.12(a), WAC 173-201A-070(1), 40 CFR §§ 131.6, .12(a), WAC 173-201A-030. Among those uses that must be protected are fish and wildlife, recreation and industrial (including hydropower) 40 CFR § 131.10(a). The fundamental purpose of numeric criteria is to protect beneficial and designated uses, i.e., “states must adopt those water quality criteria that protect the designated use.” 40 CFR § 131.11(a). Thus, numeric criteria exist to support the beneficial and designated uses, not as ends in themselves, and not as something to be achieved regardless of the consequences for beneficial and designated uses (Chelan PUD 2006).

The Washington State Pollution Control Hearings Board (PCHB) recognized this in a decision upholding Ecology’s 401 certification for the Lake Chelan Hydroelectric Project. In rejecting the notion that numeric criteria should be pursued even when the result would harm beneficial and designated uses, the PCHB stated that “the primary aim of the § 401 certification … is to meet water quality standards *by complying with the intent and the substance of the standard rather than its numeric form*.” PCHB No. 03-075, Final Order, at 15. (emphasis added).

The example above illustrates the need to assure overall compliance with the intent and substance of the WQS, rather than seeking to achieve mechanical compliance with the numeric criteria, regardless of the consequences for beneficial and designated uses. Ecology’s Determination of Compliance Letter (2015) has stated that despite the Rocky Reach Project not achieving full compliance with the TDG numeric criteria, the aquatic life designated use has not been adversely affected. Furthermore, as Chelan PUD proceeds with TDG management at the Rocky Reach Project, Section 5.4(1)(d) of the Project’s 401 Certification states that probable and possible impacts to fish species must be considered in the evaluation of any additional “reasonable and feasible” TDG abatement methods. The concept of achieving a balance between achieving mechanical compliance with the numeric criteria while also considering the potential impacts for beneficial and designated uses (e.g., aquatic life, recreation, etc.) serves as the basic framework for a risk based assessment that will be implemented to evaluate potential TDG abatement alternatives for the Rocky Reach Project (see Section 3.0 and 4.0 below).

2.4.2 TDG in the Mid-Columbia River System

2.4.2.1 Mid-Columbia River Non-Federal Projects

As mentioned previously, the mid-Columbia HCA is an agreement focused on coordinating the power operations of the seven mid-Columbia projects toward meeting daily load requirements through the assignment of "coordinated generation" through Central. Five of these mid-Columbia River projects (from upstream to downstream – Wells, Rocky Reach, Rock Island, Wanapum and Priest Rapids dams) are operated by public utilities (i.e., Douglas, Chelan and

Grant counties) under FERC licenses and all are located downstream of the two mid-Columbia River federal projects discussed below. Each project in the system has preferred operating criteria depending upon generation requests and environmental conditions and requirements. The preferred forebay elevation at each non-federal project is a combination of power demand, discharge from upstream projects and maximum and minimum elevations located within each projects respective FERC license. Central River Control is used to maintain preset reservoir levels in order to meet load requirements and prevent involuntary spill, which has the potential to produce TDG. These preset reservoir levels are maintained at each project through management of a positive or negative "bias" which assigns a project more or less generation depending on whether the reservoir elevation should be increased or decreased in order to maximize system benefits and minimize involuntary spill and resultant TDG. The agreement allows for intermittent trade-offs of maximum benefits at individual dams to spread benefits throughout the system in a coordinated fashion while meeting environmental, recreational, and power generation requirements (Kiefer 2009).

2.4.2.2 Mid-Columbia River Federal Projects

Chief Joseph Dam is part of the FCRPS, which comprises 29 dams. It is located 30 miles upstream from the Wells Dam and 52 miles downstream of Grand Coulee Dam and operates as a run-of-river hydropower project, fluctuating less than six feet in elevation over a normal year in Lake Rufus Woods (the reservoir behind Chief Joseph Dam). Chief Joseph Dam has no upstream fish passage and is considered the furthest upstream point of anadromous fish distribution in the Columbia River basin. Water discharge from Chief Joseph Dam is generally dispatched by the BPA for the production of electricity and by the USACE for flood control purposes (USACE 2000a).

Grand Coulee Dam, also part of the FCRPS, is operated by the USBOR, and is located at Grand Coulee, Washington. Grand Coulee was completed with 18 generating units in 1942, prior to Chief Joseph Dam, and impounded what is now called Lake Roosevelt. The Project is authorized by Congress for uses associated with flood control, power production, and irrigation. The reservoir is managed by the USACE to reducing flooding downstream in the spring and to enhance electric generation in the fall and winter. Complete refill of Grand Coulee is normally targeted for June 30 each year and then dropped near elevation 1280 feet or higher by the end of September (full pool elevation is 1290 feet). Fall draft is limited to elevation 1265 feet by December 31 to ensure an 85 percent confidence of refill to the flood control rule curve on the planning date of April 10 per the supplemental Biological Opinion (BO; NMFS 1998) and to be consistent with previous operations and studies conducted during Endangered Species Act (ESA) consultations (USACE 2000a).

The greatest water quality concern related to Chief Joseph and Grand Coulee dams is TDG levels in both Rufus Woods Reservoir and the Columbia River below the Chief Joseph Dam. Due to the height of the spillway and the configuration of the stilling basin at Grand Coulee Dam, TDG levels can easily exceed 110 percent. This problem is most acute during the spring and summer when both Grand Coulee and Chief Joseph dams are spilling water due to high runoff or the anticipation of freshet conditions causing drafting at Grand Coulee in anticipation of capturing snowmelt entering the Project, and insufficient power demand does not allow all inflow to pass through generating units (USACE 2000a).

In 2004, Ecology, the Spokane Tribes of Indians, and the U.S Environmental Protection Agency (EPA) developed a total maximum daily load (TMDL) report for TDG in the mid-Columbia and Lake Roosevelt (Pickett et al. 2004). The document indicates that compliance in the Chief Joseph Dam tailrace is carried out by Ecology, the Colville Confederated Tribe and EPA. Ecology's standards differ between Phase I and Phase II of implementation of the TMDL with Phase I having identical WA State WQS TDG criteria during fish passage periods and Phase II being 73 mm of Hg (or 110 percent) in the tailrace of Chief Joseph up to the mouth of the Okanogan River (Pickett et al. 2004). In addition, TDG standards in the tailrace of Chief Joseph Dam are enforced by the Colville Confederated Tribes, whereby standards are 110 percent as measured at any time of year along the reservation boundary, including the Chief Joseph tailrace, and as an instantaneous measurement (Pickett et al. 2004; Colville Tribe 2010).

To address the issue of spill and resultant TDG production, the USACE and USBOR identified a preferred alternative of installing flow deflectors at Chief Joseph Dam combined with joint operations at Grand Coulee Dam (USACE 2000a). The joint operating policy, aimed at more effective management of TDG supersaturation at Grand Coulee and Chief Joseph dams, can limit TDG producing operations (i.e., spilling out of regulating outlets) and increase generation at Grand Coulee thereby providing additional spill capabilities at Chief Joseph Dam without increasing TDG for a comparable level of flow and spill.

2.4.2.3 Federal Gas Abatement and Spill Priority

In response to Reasonable and Prudent Alternative (RPA) 136 in the NMFS 2000 BO, construction of the spillway flow deflectors was initiated in 2005 at Chief Joseph Dam (BPA et al. 2010). Although Chief Joseph Dam does not have fish passage, during Phase I testing of the TMDL implementation (2004-2010), the project was operated under the higher TDG load allocation criteria normally reserved for projects with beneficial fish passage via spill (i.e., similar to fish passage TDG exemptions issued annually at non-federal mid-Columbia River dams). The purposes for the Phase I TMDL load allocation tests were: (1) to evaluate whether the joint operations of Grand Coulee and Chief Joseph dams could produce less TDG; and (2) to authorize TDG in excess of the standard during the Phase I spill deflector construction and testing at Chief Joseph Dam. Testing of Chief Joseph Dam spill deflectors was completed in 2009 (BPA et al. 2010).

Since the completion of spill deflectors at Chief Joseph Dam in 2009, there has been a marked shift in federal spill operations resulting in a significant increase in the amount of spill at Grand Coulee and Chief Joseph dams. This increase in spill has resulted in a dramatic increase in the volume of water supersaturated with TDG entering the non-federal project reach of the mid-Columbia River. A primary factor for increased spill has been the significant development of new wind generation in the region resulting from renewable portfolio standards and federal production tax credits, investment tax credits, and Renewable Energy Credits. Currently, 5,100 MW of wind generation are connected to BPA's transmission system and this is expected to grow another 3-4,000 MW by 2025[2]. Wind generation usually occurs at night or in the spring when the generation is not needed. However, the power grid requires that system load and generation be balanced at all times. System imbalances can result in system frequency shifts that damage electronic equipment or cause system protection devices to trip. Federal regulations require system operators to maintain system frequency at 60 hertz (Hz) at all times. Hydropower is one of the best generation sources for managing system frequency and load/generation imbalance due to wind (e.g., wind integration or dynamic capacity). However, curtailing hydroelectric power generation to facilitate the integration of wind into the electric grid often results in increased spill.

Contrary to the trends observed recently, the joint operations of Chief Joseph and Grand Coulee reservoirs and installation of flow deflectors at Chief Joseph Dam were originally intended to reduce TDG levels within the mid-Columbia River. This is recognized in the 2008 BO for the FCRPS (NMFS 2008), in the Environmental Assessment (EA) and Finding of No Significant Impact for the flow deflectors (USACE 2000b), and in the FCRPS TDG TMDL (Ecology et al. 2004).

If operations at Chief Joseph Dam continues to increase spill and increase the volume of water supersaturated with TDG entering the non-federal reach of the mid-Columbia River at greater frequencies, the mid-Columbia River PUD projects will have a more difficult time meeting state WQS due to increased TDG exceedances of incoming waters.

2.5 Rocky Reach Project TDG Activities

Chelan PUD has been spilling water for downstream fish passage at the Rocky Reach Project since 1976. Spill is a tool used for improving survival of anadromous salmonids during their downstream migration and is part of the “tool box” being implemented to meet HCP survival standards. Spill can also occur when high stream flows exceed the hydraulic capacity of the powerhouse or, occasionally, when energy demand is low and river flows are high. In the Columbia River basin, a regional effort has been undertaken to monitor and control TDG and its biological effects. Chelan PUD has participated in that regional effort since 1982 (Chelan PUD 2006).

Since 1982, Chelan PUD has monitored TDG at the Rocky Reach Project. Since that time, TDG management has evolved based upon information gathered from numerous evaluations, continued refinements in monitoring, and improved coordination. These activities have resulted in a better understanding of TDG production dynamics and the identification of potential alternatives to further improve TDG management at the Project.

2.5.1 Relicensing Studies

2.5.1.1 TDG Analysis 1997-2000

Early in the Rocky Reach Project relicensing process, Chelan PUD funded a review of TDG monitoring and project operations data for the years 1997-2000. This study (Parametrix 2000)

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[2] Available at https://www.bpa.gov/Projects/Initiatives/Wind/Pages/default.aspx.

examined the relationships between incoming levels of TDG, total flow, spill volumes and spillgate configurations at Rocky Reach Dam, and the levels of TDG recorded at the downstream monitoring site and at the forebay of Rock Island Dam. The analysis of monitoring data determined that spill at the Rocky Reach Project has a lower TDG entrainment effect than is observed at most other Columbia River projects. During the years of 1998-2000, TDG levels increased only slightly during the spill period (1-3 percent of saturation on average, range –5 percent to +15 percent). Average TDG levels during 1998-2000 remained below 110 percent of saturation, although point measurements ranged from 100 percent to 120 percent of saturation. These conditions occurred with total river flows ranging from less than 100,000 cfs to about 275,000 cfs. Increases in TDG levels were only slightly greater at higher river flows (Parametrix 2000).

The analysis determined that the TDG level below the Rocky Reach Project is more influenced by the TDG level arriving at the Project than by the level of spill at the Project, confirming earlier observations from annual reports between 1996 and 1998 (Chelan PUD 2005). However, the incoming TDG concentrations to the forebay of the Project tended to be higher with higher water flow, lending to higher concentrations at monitoring locations downstream.

The analysis also indicated that different types of spill operations can affect the entrainment of air and the resultant TDG level. Study results suggested that configurations using a greater number of gates tend to minimize the increase in TDG from the forebay to the tailrace but could not identify a precise relationship between configuration and decreases in TDG due to confounding effects such as the TDG levels of incoming water and the varying degree of mixing of powerhouse and spillway flows at the downstream sampling location (Parametrix 2000). The analysis also determined that TDG levels dissipate somewhat when traveling through the Reservoir, with more reduction in TDG at lower flows than higher flows (Parametrix 2000).

2.5.1.2 Near Field Effects Study

In 2002, a study of near-field effects of specifics spillgate and powerhouse operations on TDG levels was conducted by the USACE (2003). The objective of the study was to improve the understanding of how different gate settings affect the level of TDG produced for specific volumes of spill. For near-field effects, TDG measurements are made in close proximity to Project structures which avoids the compounding effects of TDG levels of incoming water and variability associated with mixing spill and powerhouse flows as noted in the Parametrix (2000) study. TDG measurements were taken at an array of near-field locations upstream and downstream of Rocky Reach Dam during the week of April 26 to May 3, 2002.

A number of different spillgate configurations were tested to determine how best to manage spill operations to limit TDG levels. The spillway flow ranged from 10.6-61.0 kcfs during the study. In addition, two different modes of powerhouse loading were tested by concentrating discharge through either the south or north end of the powerhouse. The normal (standard) spill pattern uses a variable number of spillgates, three spillgates (4, 6 and 8) for total spill volumes below 20,000 cfs, increasing the number of spillgates as needed up to 7 spillgates (2 through 8) for spill volumes above 50,000 cfs. The standard spill pattern was developed to create tailwater conditions generally conducive to upstream salmon passage (a V-shaped margin of aerated water leading to upstream fishway entrances). Discharge through individual spillgates ranged from about 4,000 to 10,000 cfs for total spillway flows of about 10 to 60 kcfs, but discharge was not evenly distributed through the spillgates. Alternative spillgate configurations included spreading spill evenly over seven spillgates, evenly over 11 spillgates, and concentrating spill into three different locations on the spillway (2 to 5, 5 to 8 and 9 to 12).

The study concluded that spillway operations at the Rocky Reach Project increased average TDG level in the Columbia River below the spillway by 1.8 to 8.6 percent over levels arriving at the Project. However, this study was conducted when the TDG level in the forebay was below 110 percent, which is rarely the case during the fish migration season. Thus, the increase in TDG level was greater than typically occurs during the fish migration season. Because TDG levels in the forebay were low, there was little opportunity to study the degassing effect of the Project's spillway, which can occur when forebay TDG levels exceed 120 percent (Chelan PUD 2006).

The standard spill pattern and a uniform pattern using spillgates 2 through 12 had the lowest TDG of the spillgate configurations tested. The uniform spill pattern (spillgates 2 through 12) produced slightly less TDG than the standard pattern for total spill levels of about 50,000 cfs. However, the powerhouse discharge was significantly higher during tests under the standard spill pattern, and mixing of powerhouse flow may have prevented observation of a greater difference between these spillgate configurations at the lower spill levels (Chelan PUD 2006).

The entrainment of powerhouse flows, mixing with spillway discharge, influenced TDG levels. Increases in powerhouse discharge while spill discharge was held constant resulted in a decrease in the maximum TDG level, which is likely due to mixing of powerhouse flow with the spillway flow. Although the mixing effect reduces the maximum TDG level measured, the entrainment of powerhouse flows into the highly aerated spill discharge results in a greater total volume of flow having elevated TDG levels (Chelan PUD 2006).

In addition to the analysis of different spill patterns, the study evaluated whether the existing fixed monitoring sites (forebay and downstream monitoring site) accurately represents the TDG levels in the river. The forebay monitoring site did represent TDG levels in the Columbia River arriving at the Project. The downstream site was found to underestimate the average TDG level across the river channel at that location by about 1 percent. Transects conducted during yearly monitoring find the downstream site is typically within 1 to 2 percent of the highest TDG level across this transect location (Chelan PUD 2006).

The USACE compared the TDG exchange (gas sorbing into and out of water) of the Rocky Reach spillway to other Columbia River hydroelectric projects. They concluded that TDG exchange at the Rocky Reach Project is similar to TDG exchange at Lower Granite Dam, which has been equipped with gas abatement technology (spill flow deflectors). The TDG level at Rocky Reach, using the standard spill pattern, reached 120 percent in the tailrace, at a spillway discharge of 62,700 cfs (131 percent of a 7Q10 flow if the powerhouse is running at full capacity). However, the Lower Granite Dam powerhouse hydraulic capacity is much lower in relationship to the 7Q10 flow for the Snake River, thus during high flow years the spill level at

Lower Granite Dam will cause much higher TDG levels than will occur at Rocky Reach Dam in high flow years.

At many federal projects on the Columbia River, a predictive model, SYSTDG, is one of the tools used to manage spill and prevent exceedances. The standard spill pattern TDG regression was tested with the SYSTDG model to evaluate its applicability to spill management at the Rocky Reach Project. SYSTDG predicted the TDG exchange at Rocky Reach Dam as a function of the forebay, background TDG level and Rocky Reach Project operations. High forebay TDG pressures reduce the allowable spillway discharge to avoid leading to excessive TDG at the fixed monitoring sites downstream of the dam. A review of historic records of TDG levels indicated that the 115 percent criterion for the forebay of Rock Island Dam, rather than the 120 percent criterion for the tailrace monitoring station, will be the location where exceedances are most likely to occur. This is particularly true when the TDG level arriving at the Rocky Reach forebay is high. The predictive error of the SYSTDG model was within a TDG level 0.3 percent over 90 percent of the study period (April 26-May 3, 2002). The SYSTDG model could be used as an additional tool to manage spill and prevent exceedances downstream from the Project.

2.5.1.3 2003 Gas Abatement Techniques Investigation

MWH was retained by Chelan PUD to investigate alternatives for TDG abatement at Rocky Reach Dam spillway. The primary purpose of the study was to develop an up-to-date bibliography on TDG abatement techniques, from existing information identify all possible gas abatement alternatives, and evaluate the most probable solutions to reduce TDG supersaturation levels downstream of Rocky Reach Dam. These alternatives were to help Chelan PUD meet state and federal TDG standards below Rocky Reach Dam, especially during the high flow season (MWH 2003).

Several steps were performed to accomplish the objectives of this study including: (1) acquisition of site-specific relevant data, information on the TDG measurements, drawings of Rocky Reach Dam, and reports; (2) interviews with key TDG abatement researchers from both the USACE and NMFS; (3) a bibliography was assembled based on references obtained from interviews and the Corps' Dissolved Gas Abatement Study report and (4) a literature review was performed and references reviewed to assess the applicability of previously studied solutions to the Rocky Reach Dam TDG issues (MWH 2003).

The study concluded that the most robust TDG data source was associated with USACE projects on the Columbia River and found that of the four characteristics most critical to TDG entrainment (i.e., spillway crest elevation, stilling basin elevation, minimum operating pool and normal tailwater depth) Rocky Reach Dam was most similar to three USACE projects but only in two characteristics. These projects were The Dalles (spillway crest elevation and stilling basin elevation), Ice Harbor (spillway crest elevation and minimum operating pool) and Lower Granite (minimum operating pool and normal tailwater depth) dams (MWH 2003).

The study identified and evaluated possible operational and structural solutions to mitigate TDG at Rocky Reach Dam. Operational solutions evaluated included maximizing powerhouse flows and spilling from the full suite of spill gates (i.e., 2 through 12). There were eighteen structural solutions evaluated that included spillway deflectors, submerged outlets, submerged outlets with deflectors, baffled spillway, side channel spillway, side channel stepped spillway, adding spillbays, raising the stilling basin, raising the stilling basin with deflectors, raising the tailrace, raising the tailrace with deflectors, new spillway gates, conversion of turbines to sluices containing throttling gates, rebuilding the powerhouse to allow for a hydrocombine design (spilling over units), V-shaped spillway, adding generation capacity, divider wall between powerhouse and spillway, and removing nappe deflectors (MWH 2003). Each alternative was evaluated against a set of criteria (8) that included TDG performance, effects to upstream and downstream fish passage, maintaining design spillway discharge, generation impacts, public use of the river, effects to operation and maintenance, and capital cost.

Results of the study indicated that both operational alternatives should be explored further. Maximizing powerhouse flows requires that the fish spill requirements be decreased and the reduced flows be passed through the powerhouse. Note however that periods of highest spill have typically occurred in the spring when flows are high and energy demand is low. The second alternative, optimizing spill from gates 2 through 12, also showed promise based on TDG measurements taken in two operational trials in spring of 2002. These data indicated that by altering the standard spill pattern, a decrease in saturation of up to 7 percent might be achieved during maximum fish spill of 62,500 cfs. Since there is only a small amount of data for this alternative, further data should be gathered (MWH 2003) especially since the original spill pattern is implemented to support upstream adult fish migration.

With regards to structural alternatives, the study concluded that most alternatives were either very expensive, exposed downstream migration fish to injury, had low TDG benefit to cost or a combination of the above. The study determined that in addition to the two operational alternatives, structural alternatives recommended for further investigation included flow deflectors, raising the stilling basin, raising the stilling basin with flow deflectors, raising the tailrace, raising the tailrace with deflectors, and removing existing nappe deflectors on spill bays (MWH 2003).

2.5.1.4 2005 USACE Operational and Structural TDG Assessment

Chelan PUD hired researchers from the USACE Engineer Research and Development Center (ERDC) to further evaluate the alternatives recommended for further evaluation by MWH (2003). In addition to the eight alternatives identified from the previous study, researchers included consideration of an entrainment cutoff wall to partition powerhouse flows from spillway flows (Schneider and Wilhelms 2005).

The analysis of the nine TDG management alternatives was based upon direct observations of TDG exchange characteristics at Rocky Reach Dam and at other projects with a wide range of TDG management attributes. In addition to a review of physical data, the theoretical basis for TDG gas transfer and best engineering judgment was employed to develop the assessment.

The assessment concluded that the most reliable method to not impact the TDG loading in the Columbia River at Rocky Reach Dam would be to reduce or eliminate spill. However, as noted earlier, high spill in the Columbia River basin often coincides with periods of high spring flows, wind generation, and low energy demand. As such, maximizing generation during a period when demand is low or eliminating spill entirely is likely not a realistic solution in the mid-Columbia; rather managing expected spill through coordination and better developed operational approaches may be a more promising approach. Furthermore, the current operating regime at the Project includes consideration for maximizing flows to reduce spill while operating for peak efficiency. With regard to uniform spill patterns on bays 2 through 12, the study concluded that additional field tests would be required to further quantify the TDG exchange benefits.

Most of the structural alternatives were identified to exhibit limited potential to effectively manage TDG saturation at Rocky Reach Dam primarily because of the relatively low rates of TDG exchange associated with current spill operations. The limited channel width of the Columbia River required the spillway and stilling basin at Rocky Reach Dam to take on a unique design aimed at efficiently dissipating the energy contained in spill over a short distance. The spillway and stilling basin include hydraulic structures like the nappe deflector, continuous baffle, and high stilling basin end sill that provides sufficient energy dissipation over the short length of the stilling basin. These hydraulic structures have the unintended impact of moderating the TDG exchange characteristics at Rocky Reach Dam. The combination of efficient energy dissipation in a shallow stilling basin with an end sill that produces a surface oriented jet entering the adjoining tailwater channel result in TDG pressures that are similar to projects with retrofitted TDG abatement structures (Schneider and Wilhelms 2005). Due to these unique characteristics, the assessment found that current TDG exchange performance at Rocky Reach Dam is comparable and in some cases superior to projects with spillway flow deflectors. Other alternatives evaluated such as raising the stilling basin elevation, raising the tailwater channel, and removing nappe deflectors were judged to provide minimal benefits to manage TDG saturation (Schneider and Wilhelms 2005).

Structural measures which were identified as having potential to further manage TDG saturation at Rocky Reach Dam were the entrainment cutoff wall and spillway flow deflectors in combination with a raised tailwater channel. The entrainment of powerhouse flow was estimated from the results of the 2002 near-field TDG exchange study and used to estimate the TDG benefits associated with an entrainment cutoff wall. The reduction to the average TDG saturation in the Columbia River below the Project was estimated to range up to 2.6 percent saturation when compared to current conditions. This alternative would have little influence on the maximum TDG saturation attained in spill but would reduce the TDG loading to the Columbia River and on TDG levels delivered to downstream projects. The amount of TDG abatement is smaller during voluntary spill conditions and goes to zero as the spill become small (Schneider and Wilhelms 2005).

The TDG exchange properties at Ice Harbor Dam have consistently exhibited the lowest TDG exchange properties of dams actively spilling for fish passage in the Columbia River Basin. The combination of spillway flow deflectors and a shallow tailwater channel has been identified as the cause for the low rates of TDG exchange. If the spillway, stilling basin, and adjoining tailwater channel at Rocky Reach Dam were rebuilt to resemble the conditions at Ice Harbor

Dam, an improvement to TDG management could be achieved. However, the benefits of TDG reduction were estimated to range up to 2.7 percent saturation or similar to the impacts attributed to an entrainment cutoff wall (Schneider and Wilhelms 2005).

Lastly, the study noted that further evaluation of the small suite of identified operational and structural TDG management alternatives must also consider the impacts to other beneficial uses of the river prior to further consideration for adoption. This recommendation is consistent with the requirements of the FERC Project License and Ecology's 401 Certification in addition to the discussion summarized in Section 2.4.1 above.

2.5.2 Post-relicensing TDG Compliance Activities

Since filing the Rocky Reach Project Final License Application on June 30, 2004 (and receipt of a new operating license on February 19, 2009), Chelan PUD has continued to implement activities toward improving TDG management within the Rocky Reach Project. Many of the TDG Protection, Mitigation and Enhancement activities are summarized in the Rocky Reach Project Water Quality Management Plan (Chelan PUD 2005) and are described below.

2.5.2.1 Spill Testing 2011-2012

Chelan PUD conducted a study to identify differences in TDG levels produced using four spill gate configurations (Parametrix 2013). The four spill gate configurations included Fish Spill (standard gate configuration for adult fish guidance using gates 2-8), TDG Spill, Shallow Arc Spill, and Flattened Spill. The latter three configurations used gates 2-9 and gates 11-12 in 2011 (gate 10 inoperable due to maintenance), and gates 2-10 and gate 12 in 2012 (gate 11 inoperable due to maintenance). Each configuration was tested under routine operating conditions to provide a record of TDG levels produced as a means to guide future spill gate operations. Data was obtained for spill periods of 2011 and 2012 for the forebay and downstream monitoring locations.

Results indicated that the Fish Spill configuration tended to increase TDG downstream from the dam and produced the highest TDG levels of the four configurations tested. The TDG Spill, Shallow Arc Spill, and Flattened Spill configurations tended to produce small reductions in TDG levels from the forebay to the downstream monitoring station. Given the similar number of gates used between these three spill gate configurations, the differences between configurations was not always clear or consistent. However, the Flattened Spill configuration tended to produce more consistent and slightly greater reductions in downstream TDG levels, than the other configurations (Parametrix 2013).

The basic difference between Fish Spill and the other configurations is the number of gates used to discharge a given amount of flow. Fish Spill used only seven gates, while the other configurations employed ten gates each. Spreading spill over a greater number of gates generally tends to minimize the production of TDG levels downstream (Parametrix 2013).

2.5.2.2 GAP and TDG Annual Reporting

Consistent with years prior to the completion of relicensing, Chelan PUD continues to submit and operate under an Ecology-approved GAP to support downstream juvenile fish passage.

Chelan PUD coordinates the development of the GAP each year with the HCP CC and RRFF using the best available information to minimize TDG while maximizing the benefits of spill for ESA-listed anadromous salmonids. Reporting of the Project's TDG management activities is submitted annually to the FERC and Ecology.

2.5.2.3 TDG Monitoring

Chelan PUD maintains two fixed monitoring stations at Rocky Reach Dam to monitor TDG levels annually from April through August in the forebay and tailrace for the term of the License and any subsequent annual licenses, or until such monitoring is no longer required by Ecology, whichever occurs sooner. The monitoring point for TDG in the tailrace has been moved to near the JBS outfall. TDG is monitored hourly from April through August at these two stations and data is posted on a daily basis to Chelan PUD's web page and various web-accessible databases used by Ecology and regional fish management agencies. In addition to the two Rocky Reach Dam TDG monitoring locations, TDG data is also collected in the Rock Island Dam forebay occurs to support GAP requirements.

2.5.2.4 Operation Plan for Fish Passage Spill Management

Chelan PUD manages voluntary spill levels provided for fish passage in real time in an effort to continue meeting TDG numeric criteria, using an Operational Plan for TDG, while meeting the HCP survival objectives. An Operational Plan is filed each year as part of the Project's GAP.

Under the Operational Plan for TDG, the Project's operations personnel monitor TDG levels hourly. If the previous six-hour average TDG level in the tailrace at the JBS outfall is at or above 120 percent, or the instantaneous TDG level is at or above 125 percent, the voluntary spill volume will be reduced by 3 kcfs, or as necessary to achieve an instantaneous TDG level below 120 percent. The new spill volume will be monitored for an hour. If the next six-hour average TDG level is not less than 120 percent, the spill will be reduced by another 2 kcfs and monitored for an hour. The cycle continues, with the spill reduced by 2 kcfs until the average TDG level of the previous six-hour period is less than 120 percent and remains at less than 120 percent through the next full hour. If the instantaneous TDG drops below 118 percent for one full hour, the spill will be increased by 2 kcfs and monitored. The objective is to maintain as much of the spill level scheduled for fish passage operations as possible, without exceeding the tailrace TDG numeric criteria. In 2016, voluntary spill at Rocky Reach was implemented only for subyearing Chinook and consisted of nine percent of the daily average flow.

If the TDG level in the forebay of Rock Island Dam exceeds 115 percent, Rock Island operations personnel notify Rocky Reach operations personnel immediately. If the TDG level in the Rock Island forebay is greater than 115 percent and the TDG level in the forebay of Rocky Reach is less than 115 percent, the voluntary spill volume at Rocky Reach will be reduced by 3 kcfs for two hours. If, after two hours of reduced spill, the Rock Island forebay TDG levels are still above 115 percent, the spill will be reduced another 2 kcfs. If, subsequently, the instantaneous TDG level in the forebay of Rock Island is less than 113 percent, spill will be increased to the level necessary to comply with the TDG level of 115 percent. Since the TDG level in the Rock Island forebay is affected by mixing of powerhouse flows with spillway flows at the Rocky Reach Project, Rocky Reach operations personnel may develop additional protocols to adjust spill levels based on changes in powerhouse flow levels.

2.5.2.5 Minimizing Voluntary Fish Passage Spill

Chelan PUD minimizes voluntary spill by implementing the HCP Agreement to meet survival objectives, using measures other than spill, such as the JBS, as much as practicable. Minimizing the use of spill to meet survival objectives reduces TDG levels caused by the Project. Reducing the use of voluntary spill is the most effective way to reduce TDG levels, as evidenced by the low TDG levels observed in 2004. As noted in Section 2.5.2.3, Chelan PUD provides Ecology with an Operations Plan for use of voluntary fish passage spill each year.

2.5.2.6 Minimization of Spill Due to Maintenance

Chelan PUD minimizes spill, to the extent practicable, by scheduling maintenance based on predicted flows. The objective throughout the year is to maintain adequate hydraulic capacity to pass expected inflows through the powerhouse. The Project rarely spills for lack of hydraulic capacity. The continued improvement in maintenance planning to assure turbine unit availability during high flow periods is the most effective action that can be taken to prevent unplanned spill and meet the TDG numeric criteria.

2.5.2.7 Avoidance of Spill Past Unloaded Units

Chelan PUD avoids spill by continuing to participate in the HCA, or any successive agreements to which Chelan PUD may be a party, to the extent it reduces TDG, and manage its operations in an effort to minimize spill past unloaded turbine units caused by imbalances between upstream flow releases and projected power demand. Continued improvement in the efficient operation of the coordinated system is an ongoing priority for Chelan PUD. This effort will continue to reduce the already very low incidence of involuntary spill, resulting in a reduction in TDG. Spill past unloaded units is infrequent and usually the result of problems with coordination of load requests and movement of water through the coordinated system. Improvements in the computer program that implements the HCA, as well as the changes to the allocation of the costs resulting from this type of spill reduce the incidence of spill past unloaded units (Chelan PUD 2006).

2.5.2.8 Maximizing Powerhouse Discharge

Chelan PUD operates the powerhouse at maximum hydraulic capacity when necessary to maintain compliance with TDG criteria. At flows near the 7Q10 level and with one turbine out of service for maintenance, the 120 percent TDG criterion could be slightly exceeded. When operated under peak efficiency, turbines C1 though C7 will each pass up to 17,150 cfs of water and turbines C8 though C11 will each pass up to 21,200 cfs of water, for a total powerhouse hydraulic capacity of 204,000 cfs. The turbine flows can be increased to a total plant hydraulic capacity of 212,000 cfs for several hours, if necessary to control TDG loading. To do so would bring the Project into compliance at the tailrace for all flows under the 7Q10 flow. During the rare events where flows exceed normal powerhouse capacity during the non-fish spill period, this same operation could be used in addition to management of active storage to avoid spill. Chelan PUD regulates forebay levels, using active storage (the 36,400 acre-feet of storage between minimum and maximum forebay levels allowed by the FERC license) to minimize spill events to the extent practicable under the HCA (Chelan PUD 2006).

2.5.2.9 Spill from Gates 2 Through 12

In 2002, limited testing was conducted of a spill configuration using gates 2 through 12. That testing indicated some potential to use that spill operation configuration to reduce TDG levels during high spill volumes (USACE 2003). The findings from the limited number of test conditions indicated a potential reduction in average TDG levels of up to 2 percent (Schneider and Wilhelms 2005). Researchers recommended consideration of future additional testing of a spread spill configuration to evaluate its potential TDG management benefits at the Project.

As discussed in Section 2.5.2.1 above, Chelan PUD, in 2011 and 2012, studied alternative spillway flow distribution patterns, in order to evaluate the potential to reduce total dissolved gas TDG levels, particularly during high spill levels (above 50 kcfs). Generally, all of the three alternative spill patterns studied resulted in lower TDG levels than the standard spill pattern. Of the three alternative patterns, the flat spill pattern (flow distributed evenly between spillway gates) had a slightly better TDG performance than the other two alternative patterns. Chelan PUD presented these findings to Ecology, the RRFF and Habitat Conservation Plan Coordinating Committee (HCP CC; Chelan PUD 2016).

During the winter of 2016, computer programming of gates 9-12 for automated use occurred so that an operational configuration using spill gates 2 through 12 could be tested and ready late 2016 and early 2017, prior to the start of the 2017 fish-spill season. Currently, it is anticipated that the gate configuration, if successful in reducing TDG, would only be used during the non-fish spill season. Chelan PUD plans to operate the new spill configuration as a pilot or test spill and further evaluate the results for a designated period of time. If upon operating under the new spill configuration, data show that optimal results are not occurring as previously evaluated, Chelan PUD shall implement adaptive management in coordination with the RRFF and HCP CC. If operation under the new spill configuration provides significant reduction in TDG, Chelan PUD will incorporate the spill configuration into its regular operations during the non-fish spill season (Chelan PUD 2016). Additionally, Chelan PUD could consult with the RRFF and HCP CC to evaluate whether a flattened spill configuration should also be considered during the fish spill season to manage TDG.

2.5.2.10 Monitoring of Aquatic Life for Gas Bubble Trauma

Gas bubble trauma (GBT) monitoring is not conducted on an annual basis at Rocky Reach Dam. However, Section 5.4(1)(c) of the Rocky Reach Project 401 Certification (Ecology, 2006) requires Chelan PUD to develop and implement a plan to study GBT below Rocky Reach Dam. On April 21, 2014, Chelan PUD received a letter from Ecology postponing the GBT monitoring until such a time as is determined to be appropriate by Ecology (Ecology 2014). Ecology is currently evaluating the need for future GBT studies below Rocky Reach Dam.

Currently, Chelan PUD, in conjunction with the Fish Passage Center (FPC) Smolt Monitoring Program, continues to conduct gas bubble trauma (GBT) monitoring at the Rock Island Bypass Trap. Random samples of 100 fish composed of spring Chinook, steelhead and subyearling

Chinook may be examined two days per week during the fish spill season (April 1 to August 31). Examinations for GBT symptoms follow a standardized FPC protocol (FPC 2009). The results of this monitoring effort are included in the GAP annual report each year.

2.5.2.11 Regional Participation

Chelan PUD continues to participate in coordination with other Columbia River operators and regulators to address regional water quality issues, including sharing the results from water quality monitoring in the Rocky Reach Project.

3.0 METHODS

3.1 Study Objective

Ecology (2015) has determined that the Rocky Reach Project is currently not in full compliance with the TDG numeric criteria but that it also does not adversely affect aquatic life. The objective of this TDG AAA, as identified in the Project License and 401 Certification, is to prepare a report that evaluates what measures, both operational and structural, may be "reasonable and feasible" to implement to further reduce TDG production at the Project including an assessment of the probable and possible impacts of each measure to fish species (Chelan PUD 2004).

3.2 Alternatives Identification

Several steps were implemented to achieve the objectives of the evaluation. First, site specific TDG information was acquired and reviewed for relevance. These data, studies, and compliance reports represent over a decade of TDG activities at the Rocky Reach Project and were comprised of TDG compliance monitoring, relicensing field and modeling activities, and post-license issuance compliance activities (Section 2.5). In addition to site-specific information, TDG assessments from facilities in the mid-Columbia River and greater Columbia and Snake River basins (i.e., local and regional) were also evaluated or considered if identified as relevant and applicable to the Rocky Reach Project.

As summarized above, the most relevant source of information available was associated with numerous site-specific studies conducted during or after the Project's relicensing process and the USACE Phase I and II Dissolved Gas Abatement Studies (DGAS) for the Columbia River Fish Mitigation Program. TDG abatement measures identified and analyzed in these assessments have already been compiled and evaluated for their potential as reasonable and feasible TDG reduction alternatives for the Rocky Reach Project (MWH 2003; Schneider and Wilhelms 2005). Although completed over a decade ago, the suite of alternatives evaluated and the final set of potential alternatives recommended for further consideration as part of these site-specific evaluations remain the state-of-the-science in TDG management and in general, represent a comprehensive set of potential alternatives available to address TDG management in the region. As such, the results and conclusions of these assessments served as the starting point for this analysis.

A suite of operational and structural alternatives were identified from the existing information presented above. Each alternative was evaluated with respect to engineering, operations, power management, and environmental resources. The review included potential operational, coordination, financial, regulatory, and environmental implementation concerns and whether additional alternatives should be included. Each alternative was evaluated against a set of criteria that included:

1. Potential TDG benefits;
2. Capital cost;
3. Operation and maintenance cost (O&M);
4. Feasibility of operational implementation;
5. Implications for generation;
6. Implications to environmental resources; and
7. Implications to public use

Section 4.0 below provides a summary of this alternatives analysis.

4.0 ANALYSIS

4.1 Operational Alternatives

Operational alternatives are typically the simplest to implement. They require less capital costs however their annual operating costs can be significant. Operational measures are generally constrained by a number of factors including power-generating requirements, existing coordination agreements, and voluntary spill for the downstream passage of juvenile salmonids as well as upstream migrating adults. In addition to the two operational alternatives (maximizing powerhouse flows and optimizing spill from gates 2 through 12) identified by Schneider and Wilhelms (2005), several other alternatives were identified in the evaluation process and are also discussed below.

4.1.1 Maximize Powerhouse Flows

Currently water passes through the spillway of Rocky Reach Dam for the following reasons: 1) excess flows at the Project to meet load/demand 2) observed flows above maximum generation of 212 kcfs and/or 3) requirements to provide fish bypass flows for outmigrating anadromous salmonids. In all three of these scenarios spilled water has the potential to increase TDG. In scenarios 1 and 3, if spill can be redirected to the powerhouse to maximize generation, then TDG loading from spill can be prevented.

At the Rocky Reach Project, the use of this operational alternative is constrained by fish spill requirements. The Rocky Reach HCP serves as the foundation for anadromous salmonid management at the Rocky Reach Project. All measures proposed in the HCP are intended to minimize and mitigate impacts to Plan species which include Upper Columbia River steelhead, yearling spring Chinook, and subyearling summer/fall Chinook; sockeye, and coho salmon. The Rocky Reach HCP provides for optional tools Chelan PUD may implement to aid in juvenile fish passage at the Project, including spill and the use of the JBS (Chelan PUD 2016). At this time, survival standards (i.e., Phase III) have been met for all spring migrants (spring/yearling Chinook, steelhead and sockeye) at Rocky Reach Dam while operating the JBS exclusively. However, summer spill is still required for subyearling Chinook and in 2016, was equal to nine percent of daily average flow. Summer spill generally begins in early June and ends in mid-August when 95 percent of the migration of subyearling Chinook has passed the Project.

Another constraint upon diverting spillway flows to the powerhouse to maximize generation is coordination with upstream operations of federal facilities. FCRPS BO requirements have resulted in limitations to the load-following capability of much of the federal power system resulting in an apparent shift of load-following to Grand Coulee and Chief Joseph, which tends to increase flow fluctuations and decrease flow predictability in the mid-Columbia River existing coordination agreements.

Powerhouse hydraulic capacity also limits the potential benefit of this alternative. The 7Q10 flow at Rocky Reach Dam is 252 kcfs and the powerhouse capacity is approximately 212 kcfs for short periods of time and with all ten units in service. Even at maximum generation, approximately 40 kcfs of spill may need to be managed to meet TDG water quality requirements. Furthermore, time periods when flows are high and compliance with TDG criteria are a concern are often coupled with periods of low electricity demand. This scenario may restrict the potential for maximizing generation at a single project in a coordinated system.

Maximizing powerhouse flows likely has potential TDG benefits and low capital cost. Positive impacts to generation and negligible impacts to public use are also anticipated. However, the magnitude of TDG benefits remains uncertain given the potential for increased powerhouse flows to mix with spillway flows (depending upon operational regimes) and as noted above, the constraints of implementing this option within a coordinated system. Furthermore, in the absence of a detailed approach for maximizing powerhouse flows, costs associated with operation and maintenance of this alternative are unknown. Lastly, putting more water through turbines could have an adverse effect to downstream migrating juvenile fish. No impacts to upstream migrating adults are anticipated. Although maximizing powerhouse flows remains a viable option, it is likely one of several approaches best utilized in combination for managing spill.

4.1.2 Optimizing Spill From Gates 2 Through 12

As discussed in Section 2.2.1.1, the standard Project spill configuration uses gates 2 through 8 with a minimum discharge per spill bay of about 4 kcfs. This configuration was designed to create a crown-shaped pattern of turbulent flow below the spillway with decreasing velocities leading toward the upstream adult fishway entrances and provides favorable guidance conditions for adult migrant salmon and steelhead. Testing of this spill configuration and alternate patterns determined this pattern was as good as, if not better than, the alternate patterns for upmigrating salmonids (Schneider and Wilhelms 2005). The same pattern is used for juvenile downstream migrating fish passage spill. Currently, during spill operations, whether for juvenile fish passage, TDG management, or for other purposes, the gates are operated via a computer automated system that follows the spill pattern (Chelan PUD 2016).

Note that although the above referenced spill configuration may be as good as, if not better, than tested alternate patterns for upmigrating salmonids, it may not be ideal for TDG. During relicensing, TDG studies indicated that a uniform spill pattern (using gates 2 through 12) produced slightly less TDG than the standard pattern for total spill levels of about 50 kcfs (USACE 2003). Additional analysis supported this observation based upon a small number of operational trials that indicated a flat or uniform pattern optimizing spill from gates 2 through 12 might decrease TDG saturation up to 7 percent during maximum fish spill of 62.5 kcfs (MWH 2003). A common recommendation of relicensing studies identified the need for additional field tests of the uniform spill pattern to better quantify TDG exchange benefits (Schneider and Wilhelms 2005). This recommendation is also reflected in Section 5.4(1)(b)(6) of the Project 401 Certification (Ecology 2006).

Chelan PUD studied alternative spillway operations using gates 2 through 12 in 2011 and 2012 (Parametrix 2013) with promising results for flattened spill patterns versus the current fish spill configuration. In 2015, Chelan PUD, through coordination with the HCP CC, requested the ability to use the flattened spill configuration during the non-fish spill season. The HCP CC approved and in the winter of 2016, computer programming of gates 9-12 for automated use was completed. Chelan PUD will begin testing the flattened spill pattern late 2016.

Preliminary spill testing indicates that optimizing spill from gates 2 through 12 has the potential to reduce TDG production at the Project. Operation and maintenance efforts to implement a more flattened spill shape when necessary are likely negligible and there would be no capital costs associated with this alternative. Since no structural alterations would be considered, the spillway would maintain its ability to pass the spillway design flow and power generation and public use would likely remain unaffected. Downstream passage of juvenile salmonids would also likely remain similar to the current condition. The primary concern with maximizing the use of spillway bays during the fish spill season is the potential impact to upstream adult passage at the Project since a wider band of spillway flows could create flow patterns that make locating upstream fishway entrances difficult for migrating adult salmonids. This alternative is promising but may require additional study to better understand TDG production dynamics at different flows and under different spill operational scenarios to identify an operation(s) that reduces TDG. Identified operations could be utilized during the non-fish spill season and if there is interest in utilization during the fish spill season, additional evaluations to determine whether there are adverse effects to upstream adult migration are recommended.

4.1.3 Scheduling Project Maintenance

Scheduling outages for project maintenance may be affected by a number of factors including the type of outage (i.e., major versus minor, unexpected versus annual maintenance) and associated duration, electricity demand and prices, overall system reserve or shortfall, river flows, and environmental requirements during the maintenance period. Generating unit maintenance is typically scheduled during the “shoulder” months when power demands are lower or when lower river flows are anticipated. Re-evaluating the factors under which project maintenance and associated unit outages are scheduled to consider seasonal peaks in TDG production as a primary consideration may be an option for improving TDG management.

As noted in Section 2.5.2.6, Chelan PUD minimizes spill, to the extent practicable, by scheduling maintenance based on predicted flows. The objective throughout the year is to maintain adequate hydraulic capacity to pass expected inflows through the powerhouse. The Project rarely spills for lack of hydraulic capacity. The continued improvement in maintenance planning to assure turbine unit availability during high flow periods is the most effective action that can be taken to prevent unplanned spill and meet the TDG numeric criteria.

In general, scheduled maintenance events at Rocky Reach Dam already consider environmental and resource requirements including upstream and downstream protection of anadromous salmonids and would not change operations and maintenance. The duration of major maintenance projects such as unit rebuilds may result in unavoidable unit outages during typical peak spill periods (i.e., spring). It is likely that any changes in prioritization of factors used to determine maintenance schedules would result in minimal benefits to TDG performance while generating unit reliability and availability could be jeopardized.

4.1.4 Modification of Existing Agreements

The Rocky Reach Project is operated under a number of agreements (coordinated and uncoordinated) that affect current operations (e.g. HCP, HCA, etc.). Evaluating existing agreements to identify potential modifications that would facilitate improved TDG management could be an option. However, any potential changes to existing agreements would require renegotiations with signatory parties. In the case of the HCA, such discussions would require the participation and approval of a number of federal and mid-Columbia PUD entities and power purchasers. Furthermore, the HCA requires that the power and non-power constraints of the individual projects be recognized in the coordination process. As such, stable and predictable river flows that would support TDG management are already an objective of this agreement.

In general, renegotiating existing agreements would be a complex and timely process with considerable financial implications. Any updated agreement would also need to consider implications for existing resource protection (i.e., ESA, public use) and regulatory compliance (i.e., FERC license) requirements. Given that existing agreements already aim to maximize generation and minimize spill on a system-wide basis, prioritizing TDG performance at a single project would likely result in a net decrease in overall protection of aquatic life designated uses and at considerable cost (e.g., compensation for replacement spill requests, system-wide effects, ESA and FERC implications, etc.; Douglas PUD 2014).

4.1.5 Gas Abatement Spill

Gas Abatement Spill is used to manage TDG levels throughout the Columbia River Basin. The Technical Management Team (including NMFS, USACE, and BPA) implements and manages this spill. Gas Abatement Spill is requested from dam operators from a reach of the river where TDG levels are high. A trade of power generation for spill is made between operators, providing power generation in a section of river with high TDG and trading an equivalent amount of spill from a project where TDG is low (Douglas PUD 2014). Gas Abatement Spill options or other agreements to trade power generation for spill could result in potential TDG benefits. In addition to the potential for an increase in operations and maintenance costs and constraints (due to coordination of an abatement program), potential impacts to environmental resources, maintenance of spillway design flows, and generation cannot be determined at this time since no specific agreement or operation schedule is currently in place.

4.2 Structural Alternatives

At many federal hydroelectric facilities on the Columbia River, substantial effort has been devoted to investigating structural alternatives for TDG reduction (MWH 2003). During the relicensing of the Rocky Reach Project, Chelan PUD contracted with the ERDC researchers who led many of the key studies on TDG management alternatives of the federal system, and these studies provide the basis for this investigation of structural alternatives. As noted above, relicensing studies began by evaluating 18 different structural TDG management alternatives for Rocky Reach Dam. However, results of the various studies indicated that many of the alternatives were either very expensive to implement, exposed downstream migrating fish to injury, had a low TDG benefit relative to cost or a combination of the above (MWH 2003). Researchers also found that most structural alternatives identified exhibit limited potential to effectively manage TDG saturation at Rocky Reach Dam primarily because of the relatively low rates of TDG exchange associated with current spill operations (Schneider and Wilhelms 2005). Results of the ERDC analyses concluded that only two structural alternatives have the potential to further manage TDG saturation at Rocky Reach Dam: the entrainment cutoff wall and spillway flow deflectors in combination with a raised tailwater channel (Schneider and Wilhelms 2005). These two alternatives comprise the structural alternatives analysis below. Factors considered in the analysis include TDG benefits, generation impacts, potential resource impacts (e.g., fish and aquatic, recreation, etc.), engineering feasibility, and capital and O&M cost. It is assumed that any structural alternative would require Chelan PUD to submit a license amendment application to FERC for approval.

4.2.1 Entrainment Cutoff Wall

Rocky Reach Dam is unusual in that the powerhouse and spillway are constructed in a right-angle arrangement that provides opposing discharges. With the powerhouse and spillway arranged at approximately 90 degrees to each other, there is the potential for the spillway discharge to mix with the powerhouse discharge prior to the entrained air reaching the surface. An interaction of this nature generally produces increases in the TDG levels. Such an interaction results in both the loss of the dilution factor provided by most powerhouse discharges and an actual increase in the TDG levels of the powerhouse water. This interaction of the two flows appears to be most likely to occur with spill from the right side (looking downstream) of the spillway and turbine discharge from the higher numbered units (Units 8-11; Parametrix 2013).

Equations were developed by ERDC (Schneider and Wilhelms 2005) to estimate the reduction in TDG loading provided by a property designed entrainment cutoff wall. The TDG level measured below the spillway at the JBS monitoring location will not change with the implementation of an entrainment wall because the TDG level of spilled water is not affected; rather the entrainment wall could reduce the amount of powerhouse discharge that gets drawn into the spillway discharge, thus reducing the average TDG loading across the entire river channel downstream of the tailrace. The entrainment of powerhouse flow was estimated from the results of the 2002 near-field TDG exchange study and used to estimate the TDG benefits associated with an entrainment cutoff wall. The reduction to the average TDG saturation in the Columbia River below the Project was estimated to range up to 2.6 percent saturation when compared to current conditions. This alternative would have little influence on the maximum TDG saturation attained in spill but would reduce the TDG loading to the Columbia River and on TDG levels delivered to downstream projects (Schneider and Wilhelms 2005).

The capital cost to design, permit, and construct an entrainment cutoff wall would be significant and would require extensive modification to the Project's structures, thus several years of design and model testing would be required before it could be approved and implemented. The TDG benefit relative to the cost appears to be low, especially since estimates of reduction noted above would likely not achieve full compliance with the TDG WQS. This option, if implemented, would also alter the flow characteristics of the tailrace in a manner that could adversely affect adult and juvenile salmonid passage and survival (Chelan PUD 2006). As such, additional consultation would be required with appropriate workgroups and agencies (e.g., RRFF, HCP CC, NMFS, USFWS, etc.) to ensure the protection of aquatic resources. There would also be additional O&M costs associated with a new structure, although they would likely be low once an entrainment cutoff wall is constructed. However, if impacts to adult and juvenile salmonid passage and survival were identified and resulted in operational constraints, these costs could be significant.

4.2.2 Spillway Flow Deflectors in Combination with a Raised Tailwater Channel

Spillway flow deflectors are concrete lips built on the lower part of the spillway and have been one of the primary methods used for TDG management at dams on the lower Snake and Columbia River (USACE 2002). Spillway flow deflectors have been installed at Bonneville, John Day and McNary dams on the lower Columbia River and at Wanapum and Chief Joseph dams on the mid-Columbia River. Spillway flow deflectors have also been installed at Ice Harbor, lower Monumental, Little Goose, and lower Granite dams on the lower Snake River. Flow deflectors direct the spill in a horizontal direction to flow across the surface of the tailrace so that it does not travel deep in the water column allowing entrained air to re-enter the atmosphere at the water's surface. Encouraging near-surface flow also prevents entrained air from reaching a depth at which gas is more readily dissolved, thereby decreasing TDG levels relative to water that plunges to depth (MWH 2003). Important factors to consider for spillway flow deflectors include deflector elevation relative to operating tailrace elevation, depth of the stilling basin, and downstream passage requirements for anadromous salmonids.

Several predictive models were developed during the DGAS program (Schneider and Wilhelms 1998a; Schneider and Wilhelms 1998b) to estimate the effects of a raised tailrace channel on TDG exchange at Columbia and Snake River projects. The TDG estimates were based on the application of theoretical and conceptual models of the gas exchange processes, an analysis of historical data, application of an empirical relationship based on near-field measurements, and an analysis of degassing in the tailrace region. Model results suggest that a rapid and substantial desorption of supersaturated dissolved gas takes place in the tailwater channel immediately downstream of the stilling basin. As the entrained air bubbles are transported downstream, they rise above the compensation depth in the tailwater channel and air bubbles strip dissolved gas from the water column (Schneider and Wilhelms 2005).

Based upon the two methods described above, this alternative could reduce TDG levels at Rocky Reach Dam by redirecting spill horizontally along the tailrace surface (avoid plunging) and promoting TDG degassing (re-entry of entrained air to the atmosphere) at the water surface. Any portion of spill flow that plunges (and entrain air) would enter a reconstructed tailwater area that would be shallower. The reduction in the plunging depth of aerated flow would promote the stripping of TDG (Schneider and Wilhelms 2005).

ERDC used the TDG exchange relationship developed for Ice Harbor Dam to estimate the TDG level in spillway flows for Rocky Reach Dam. Calculations (at 7Q10 flow with one turbine out of service) indicate that this alternative would reduce TDG in spill by 4.0 to 4.2 ± 1.2 percent. There remains considerable uncertainty in the estimates of TDG exchange associated with this alternative as applied to Rocky Reach Dam. The interaction of both the continuous baffles and the stilling basin end sill will interfere with the deflected surface jet and may alter the trajectory and TDG exchange properties of this alternative (Chelan PUD 2006).

This option would only be needed during high flows and would only be effective if the deflectors are designed to function under high tailwater surface elevations. Under normal and low tailwater elevations, studies of fish survival at Ice Harbor Dam and other dams have shown that spill defectors may decrease the survival of juvenile salmon passing through the spillway. Most of the spill at the Project is voluntary spill for fish passage, which occurs when flow is below 200 kcfs. Spillway deflectors would only be needed to abate TDG when flows approach the 252 kcfs level, but would affect fish survival during any spill, including voluntary fish passage spill. Thus, the need to protect downstream migrating salmonids may preclude implementation of this option (Chelan PUD 2006).

Similar to the entrainment cutoff wall, the capital cost to design, permit, and construct this structural alternative would be significant and would require extensive modification to the Project's structures. Further consideration would require additional site-specific hydraulic and physical modeling studies to assess the deflector design and interactions with existing spillway infrastructure; the type, amount and location of tailrace fill; and the potential performance of the alternative. The TDG benefit, although estimated to be higher than the entrainment cutoff wall, remains uncertain and is still low relative to the cost implementation. Additional consultation would be required with appropriate workgroups and agencies (e.g., RRFF, HCP CC, NMFS, USFWS, etc.) to ensure the protection of aquatic resources, primarily ESA-listed salmonids given the potential survival impacts of spill deflectors to juvenile salmonids. There would be additional O&M costs although these would likely be low once constructed. . Flow patterns in the tailrace would also be likely to change under this alternative and this could impact adult salmonid passage. Consultation and with fish management agencies would be required to evaluate impacts and this could result in operational constraints or other mitigation or protection measures. These costs could be significant but cannot be characterized at this time.

Other factors requiring evaluation include whether coffer damming would be required during construction; impacts to public use (i.e., boating) below the dam as turbulence would likely be carried further downstream; erosion; and backwater impacts resulting in reduced head and power revenue impacts.

4.3 Alternatives Evaluation

In the following section, an evaluation summary is presented in which each of the preceding alternatives is evaluated against a set of criteria.

4.3.1 Evaluation Criteria

Using the MWH (2003) report as a basis, the following evaluation criteria (listed below) and scoring metrics were developed for each alternative presented in Section 4.2.

For TDG Reduction (i.e., evaluation criterion 1 below), scoring metrics ranged from 1 to 2. A score of 1 was defined as remaining the same as at present condition and a score of 2 was defined as improvement over present conditions. For all other criteria below (i.e., criteria 2-8), scoring metrics ranged from 1 to 4. A score of 1 was defined as less desirable than present conditions; a score of 2 was defined as the same as at present conditions; a score of 3 was defined as more desirable than present conditions; and a score of 4 was defined as unknown at this time.

1. TDG Reduction: the potential for the alternative to reduce TDG below current levels;
2. Downstream Fish Passage: the potential for the alternative to impact downstream fish passage at the dam including mortality and injury;
3. Upstream Fish Passage: the potential for the alternative to impact upstream fish passage at the dam including disorientation resulting in passage delays;
4. Maintaining Design Spillway Discharge: how does the project affect the ability of the spillway to pass the spillway design flood?;
5. Generation Impacts: the potential for the alternative to impact the ability to generate electricity;
6. Public Use: the potential for the alternative to affect public use of the river;
7. O&M: the potential for the alternative to impact operations and maintenance. This includes both limitation on operational flexibility and O&M cost; and
8. Capital Cost: Four cost categories in 1,000s of dollars were identified and include $0 (no capital cost), <$20,000, $20,000-$60,000, and >$60,000. It includes the cost of design, engineering, construction, administration, and interest incurred during construction. Most costs were computed by adjusting final costs of alternatives in various studies done at USACE projects (MWH 2003). Note that the entrainment wall estimate is an approximate cost developed by HDR. The accuracy of these estimates is less than that of a feasibility level assessment and it is recommended that a more thorough design analysis be conducted to provide more accurate costs prior to considering implementation.

The evaluation is presented in Table 1.

Table 1. Evaluation summary of total dissolved gas reduction alternatives at Rocky Reach Dam.

Alternative	TDG Benefit	D/S Passage	U/S Passage	Maintain Spillway Design	Generation Impacts	Public Use	O&M	Capital Cost ($1,000)	Comments
Maximize Powerhouse Flows	2	1	2	2	3	2	4	$0	Mid-Columbia is under HCA and maximizing generation at single project may be infeasible. Impacts to downstream migrating juvenile fish.
Optimizing Spill from Gates 2 through 12	2	2	4	2	2	2	2	$0	Preliminary results indicate a TDG benefit. Highest potential for TDG benefit without additional impacts to aquatic resources.
Scheduling Project Maintenance	2	2	2	2	1	2	1	$0	TDG benefit likely minimal with unknown costs and likely increase in O&M.
Modification of Agreements	2	4	4	4	4	4	1	$0	Given multi-party agreements in place, renegotiation likely complex. Prioritizing TDG at one project would likely result in overall net decrease in resource protection and generation however scope of impact unknown.
Gas Abatement Spill	2	4	4	4	4	4	1	$0	In the absence of more specifics on a spill program, impacts to most resources are unknown.
Entrainment Cutoff Wall	2	1	1	2	4	2	1	$20,000-$60,000	Significant capital cost and low TDG benefit.
Spillway Deflectors in combination with Raised Tailrace Elevation	2	1	1	2	4	1	1	$20,000-$60,000	Spillway Deflector: Interaction of existing Project infrastructure with deflector. D/S passage concerns. Raised Tailrace Elevation: Concerns include resource protection, public use and generation impacts.

5.0 CONCLUSIONS

This TDG Abatement Alternatives Analysis (TDG AAA) has been developed consistent with Section 5.4(1)(e)(2) of the Rocky Reach Project 401 Certification (Ecology 2006). It is based upon both historic and the most current regional and site-specific TDG information regarding potential operational and structural abatement measures. It serves as the basis for consultation to determine if any additional reasonable and feasible measures may exist to meet the TDG standards for the Rocky Reach Project.

This analysis compiled all relevant site-specific and regional information regarding both operational and structural TDG abatement alternatives. Results of the literature review indicated that the most significant source of TDG abatement alternatives information originated from two sources, 1) Site specific studies conducted by Chelan PUD during and after the Rocky Reach Project FERC relicensing process; and 2) the USACE DGAS program and that these alternatives were compiled in a report by MWH (2003). Numerous TDG abatement measures identified and analyzed in these assessments had already been compiled and evaluated for their potential as reasonable and feasible TDG reduction alternatives for the Rocky Reach Project (MWH 2003; Schneider and Wilhelms 2005). Although completed over a decade ago, the suite of alternatives evaluated and the final set of potential alternatives recommended for further consideration as part of these site-specific evaluations remain the state-of-the-science in TDG management and in general, represent a comprehensive set of potential alternatives available to address TDG management in the region. Potential alternatives identified from results of these assessments formed the basis for a multi-disciplinary review regarding potential operational, coordination, financial, regulatory, and environmental implementation concerns and whether additional alternatives should be included.

Results suggest that all of the alternatives evaluated would likely produce some level of TDG benefit. However, a number of concerns regarding the uncertainty around impacts to generation, environmental resources, and the feasibility of operational implementation were identified. In addition, both of the structural measures would likely require significant capital costs to implement with reoccurring O&M costs. Any further evaluation of any of the alternatives in the future will require detailed site-specific assessment and in some cases require additional physical, hydraulic and financial evaluations to more accurately scope the TDG benefit relative to the overall implementation cost. Furthermore, previous site specific TDG assessments have noted that the current spillway infrastructure already have the unintended impact of moderating TDG exchange. Structures such as the nappe deflector, continuous baffle, and high stilling basin end sill provide sufficient energy dissipation over the short length of the stilling basin. The combination of efficient energy dissipation in a shallow stilling basin with an end sill that produces a surface oriented jet entering the adjoining tailwater channel result in TDG pressures that are similar to projects with retrofitted TDG abatement structures (Schneider and Wilhelms 2005).

Existing spillway infrastructure appears to already provide TDG benefits and coupled with the high cost, nominal TDG benefits, and implementation uncertainties of adding structural alternatives evaluated during this analysis, it may be more appropriate to continue exploring, in consultation with Ecology, the RRFF and the HCP CC, operational alternatives such as a flattened spill configuration. This would allow for a more incremental approach to evaluating TDG benefits versus costs and other potential impacts including to aquatic resources.

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